State of Alaska
Division of Governmental Coordination

Assessment of Stormwater Controls in Coastal Alaska

June 1995

MONTGOMERY WATSON

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Division of Governmental Coordination

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1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND AND OBJECTIVES

The US Environmental Protection Agency (EPA) has established "Management Measures" for control of Nonpoint Pollution in the Coastal Zone, in conjunction with the National Oceanic and Atmospheric Administration (NOAA), the agency responsible for regulations of the Coastal Zone Management Act. The Management Measures have been devised for a variety of land development activities, including resource extraction, roadways, and urban development. Management Measures cover a variety of pollutants. Of particular note is the requirement to control Total Suspended Solids (TSS) in community development. Specifically, the Management Measure calls for coastal communities to:

(a) Reduce the average annual TSS loadings by 80% after construction has been completed and the site is permanently stabilized; and/or

(b) Reduce the postdevelopment loadings of TSS so that the average annual TSS loadings are no greater than pre-development loadings.

Previous research by Montgomery Watson on behalf of the Municipality of Anchorage (Montgomery Watson, 1994) suggests that few "best management practices" (BMPs) have documented performance sufficient to reliably meet these measures. This is particularly true where Alaska's sub-arctic and arctic conditions complicate the effectiveness of such practices.

Montgomery Watson prepared this assessment of storm water controls for the State of Alaska, Division of Governmental Coordination, Coastal Management Program. The work focuses on Anchorage, Bethel, and Juneau, cities selected to represent the range of conditions typical in Alaskan coastal communities.

This assessment has been undertaken to accomplish several objectives, as follows:

- Quantify annual pre-development and post-development loadings of TSS
- Determine target load reductions to meet the management measures
- Determine appropriate best management practices
- Estimate costs to implement BMP's
- Determine the economic impacts of such costs

1.2 PROJECTIONS OF TSS LOADINGS

Development scenarios were derived for each city, on scales ranging from 5 acre residential development to 20 acre industrial development. Total annual combined rainfall and snowmelt runoff in Anchorage was estimated to range from less than 1.4 inches before development to approximately 10 inches for commercial development. Similar ranges were 0.27 to 2.52 inches for

Bethel, and 1.45 to 20.54 inches for Juneau. Typical runoff TSS concentrations were estimated to range from 81 mg/L (for Bethel) to 224 mg/L (for Anchorage commercial development).

Loadings were estimated by multiplying TSS concentrations times projected runoff on a daily basis through the year. Estimates of TSS loadings range from 48 to 56 pounds per acre per year for "predevelopment" Anchorage, and 140 to 333 pounds per acre per year after development. Estimates were higher for Juneau, due to more effective mobilization of TSS during runoff, up to over one-half ton of TSS per acre per year for commercial sites after development. Bethel estimates were much lower, due to low intensity rainfall, flat slopes, and well established vegetation.

1.3 BEST MANAGEMENT PRACTICES

Maintenance of urban runoff facilities was judged to be the best non-structural BMP for implementation, although costs and benefits were not directly quantifiable. Wet pond type sedimentation basins were judged to be the best structural controls for Anchorage and Juneau. These ponds are impractical for Bethel due to permafrost and shallow groundwater. Vegetative slope protection for embankments appears to provide the best pollution prevention function in low lying tundra areas, although the effectiveness has not been reliably quantified.

Sedimentation ponds are not viewed as effective in capturing fine particulates (<10 microns effective diameter) from runoff. This fraction of TSS typically accounts for more than 20% of the TSS load in Alaska's low intensity storms. Therefore, it was concluded that the 80% removal management measure is not attainable even with the BMP judged most cost effective for Alaska's communities.

1.4 COSTS AND ECONOMIC IMPACT

In most instances, reduction in loadings to predevelopment conditions was judged to be less stringent than the 80% reduction level. Costs were estimated for 3 Anchorage and 2 Juneau development scenarios based on minimum sizing criteria for effective sedimentation pond development.

Annual costs for sedimentation ponds range from $490 per developed industrial acre to over $1640 per developed residential acre. This represents approximately 0.5 to 0.75 % of the annual cost of an industrial or commercial enterprise, or nearly 5% of annual household income for a residence.

Another measure is on the basis of total cost per pound of pollutant removed. For a twenty acre industrial development, this can be as low as $3.00 per pound of TSS. Smaller commercial and residential developments are limited by sizing criteria, forcing costs up to as much as $26.00 per pound of TSS for a 5 acre residential development in Anchorage.

2.0 INTRODUCTION

2.1 STUDY OBJECTIVES

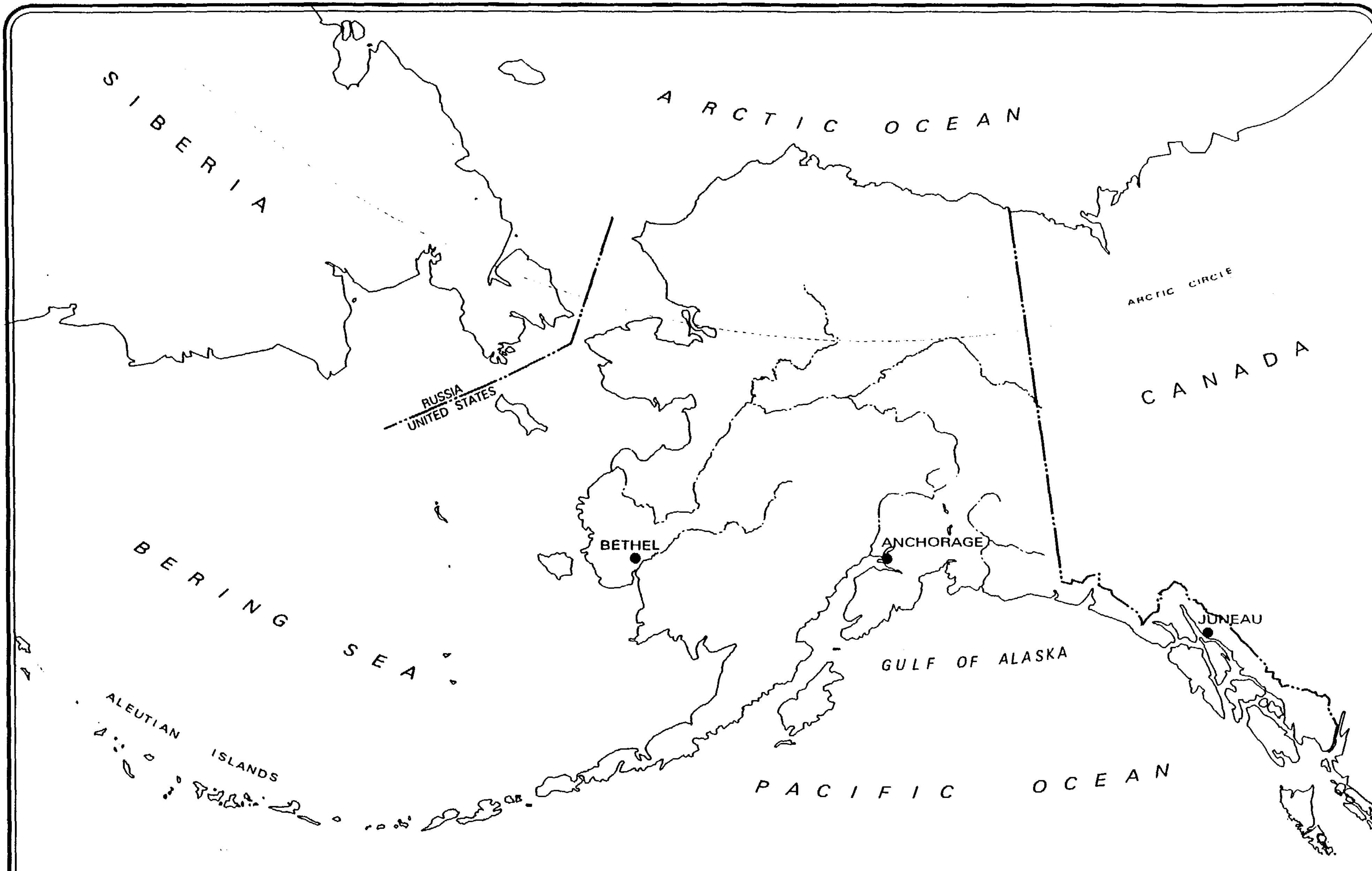
The purpose of this study is to determine the costs of stormwater quality controls to meet federal management measures for the reduction of suspended sediments from new urban development.

Suspended sediment from stormwater runoff in urban areas constitute the largest mass of pollutant loading to surface waters. NOAA and EPA have established management measures for total suspended sediment (TSS) for new development in urban areas. The goal of this report is to present an economic analysis of TSS controls for stormwater in coastal Alaska consistent with EPA guidelines and to provide useful information to Alaskan communities for management of TSS in urban stormwater.

Objectives of the study:

- Quantify TSS pre and post development loadings
- Determine target TSS load reductions for two specified management measures:
  - 80% removal
  - removal to predevelopment conditions
- Determine appropriate best management practices (BMPs) to meet both management measures and to meet current local stormwater quality standard
- Estimate the costs to implement appropriate BMP
- Determine the economic impacts of these costs

Each objective is carried out for each of three municipalities, Juneau, Anchorage, and Bethel for new development. The communities are located on the map in Figure 1. New development is characterized by three scenarios for each municipality: residential, commercial, and industrial land use. For each scenario, one structural BMP was to be chosen for each of the two TSS reduction goals. Although this study describes non-structural controls for TSS, there is not enough data to determine if the controls are sufficient to meet the management measures for new development or to estimate the costs associated with them, especially if they are implemented on a site-specific basis.



MONTGOMERY WATSON

Anchorage, Alaska

FIGURE 1

LOCATION MAP

22 BACKGROUND

The NOAA and EPA Coastal Nonpoint Pollution Control Program Management Measure for new urban development, which includes urban redevelopment, new or relocated roads, highways and bridges, requires:

" (1) By design or performance:

(a) After construction has been complete and the site is permanently stabilized, reduce the average annual total suspended solid (TSS) loadings by 80 percent. For the purposes of this measure, and 80 percent TSS reduction is to be determined on an average annual basis,* or

(b) Reduce the post-development loadings of TSS so that the average annual TSS loadings are no greater than redevelopment loadings, and

(2) To the extent practicable, maintain post-development peak runoff rate and average volume at levels that are similar to pre-development levels.

* Based on the average annual TSS loadings from all storm less than are equal to the 2-year/24-hour storm. TSS loadings from storms greater than the 2-year/24-hour storm are not expected to be included in the calculation of the average annual TSS loadings."

(in Section II. A. New Development Management Measure (EPA, 1993))

These guidelines do not explicitly included snowmelt TSS loading in the calculation for average annual TSS loading. However, they don't explicitly exclude it, either. In order to limit the scope of this study, the following procedure has been adopted.

TSS loading from snowmelt is quantified in Section 3 of the report, in order to present a complete picture of the annual TSS loading. The TSS removal of the chosen BMP for snow melt runoff is estimated, but the BMP is not sized to treat snow melt runoff to the (a) and (b) criteria.

The BMPs are selected and sized to meet the (a) and (b) criteria based on their ability to meet treat the annual TSS loading for rainfall events up to the 2-year/24-hour storm (May through September for Anchorage and Bethel; February through October for Juneau).

3.0 BASELINE CONDITIONS OF INDICATOR MUNICIPALITIES

3.1 INTRODUCTION

The purpose of this section is to define the hydrologic and TSS loading conditions in each indicator municipality. These conditions will provide the bases for BMP selection and cost analyses in sections 4 and 5. TSS loadings for urban basins are caused by runoff events. Runoff events, in turn, are caused by rainfall and by snowmelt. Annual timing and amounts of runoff and TSS loading are variable because of the influence of local meteorological conditions.

In the following sub-sections, the rainfall, runoff, soils conditions and TSS loadings are described in general and then in particular for each municipality. Local drainage conditions are described and scenarios are developed that characterize expected site development sizes and conditions for the three land use categories (residential, commercial and industrial). The typical year's runoff and TSS loads for each scenario are quantified. Finally, local stormwater quality regulations for each community are discussed and a summary of local economic conditions is presented.

3.1.1 Typical Year

In order to obtain annual TSS loadings, a "typical" year, in terms of precipitation, was identified from available weather service records for each municipality. A daily runoff rate was estimated based on the daily rainfall or snowmelt and, from these runoff rates, daily TSS loadings were generated. Because of the variability of precipitation events and the short record period of readily available data, the "typical" year may vary considerably in individual months from the long term record. In spite of this discrepancy, the use of actual rainfall records was assumed to be more representative of actual conditions than a simulated series would have been. The typical year for Juneau and Bethel were determined by analysis of annual climatological summaries for years with complete records during the period 1980 through 1993. A typical year for Anchorage was suggested by the Municipality of Anchorage (MOA).

3.1.2 Rainfall

Rainfall events greater than 0.1 inches were identified in the rainfall records for the typical year. For all three municipalities, no daily rainfall in the chosen typical year exceeded the 2-year 24-hour event determined for the location by the U.S. Weather Bureau in Technical Paper 47 (TP 47) (Miller, 1963). Professional experience in Alaska has found that TP 47 consistently overestimates rainfall intensities for any recurrence interval. As a consequence, the use of this document often leads to an overestimate of the number of rainfall-runoff events. This will consequently lead to an overestimation of the TSS loadings for rainfall events that would be subject to management measures. Before management measures are implemented, a more refined estimation of the 2-year 24-hour event should be made for specific localities.

3.1.3 Runoff

TSS loadings from urban basins is mobilized from the ground by runoff events. Coastal Alaska's runoff events fall in three general categories: summer/fall rainfall events, winter thaws, and spring snow melt.

3.1.3.1 Rainfall Runoff

Runoff due to rainfall is influenced by a number of factors, the primary ones being the soil types and percent imperviousness of the site, rainfall intensity, and antecedent moisture conditions. In developing a rainfall-runoff relationship, site specific data is the most reliable. For ungaged locations, other methods have been developed.

For Anchorage, some site specific rainfall-runoff data was available for developed urban basins. An equation, developed by the USGS (Brabets, 1987) based on data from three basins in the Anchorage area, was used to model the rainfall-runoff relationship in the Anchorage area. The equation has the following form:

$$VOL = 0.39 * (RF)^{1.10} (DA)^{0.14} (PEIA)^{0.38} \qquad (1)$$

where VOL is volume of runoff, in inches
RF is total storm rainfall, in inches
DA is drainage area in acres
PEIA is percent effective impervious area

This equation has been calibrated for basins of less than 38 acres that have effective imperviousness less than 70%, for storm rainfall events that are less than 0.5 inches. Because this equation was calibrated for Anchorage, it was used to determine rainfall runoff for Anchorage only.

For Bethel and Juneau, no site specific data was available. For these two municipalities, the method described in the USDA Soil Conservation Service's (SCS) Technical Release 55 (TR-55) was used to estimate runoff response to rainfall. TR-55 presents a simplified procedure to calculate storm runoff volume and is applicable to small urbanizing watersheds. This method estimates the runoff volume for a 24 hour storm event, based on two parameters: a factor, or curve number (CN), that reflects the soil type and imperviousness of the site, and the depth of rainfall.

$$Q=\frac{(P-.2*S)^2}{(P+.8*S)} \qquad (2)$$

where P=rainfall in inches
Q=runoff in inches
$S=\frac{CN}{1000}-10$

There are limitations on the use of this equation; both with respect to precipitation and the CN.

SCS suggests that this equation is less accurate when runoff is less than 0.50 inches. This is the case particularly in Bethel, and for a majority of the rainfall events in Juneau. The TR-55 method predicts lower flows than does another standard method, the Rational method. The Rational method, which predicts flow as the product of rainfall, basin area, and percent impervious, was developed to estimate peak flows (Sheaffer, 1982). It was not developed for the study of runoff volume, but approximations can be made by dividing the flow by the basin area. However, it was used here to serve as a check on the results from the TR-55 method. The TR 55 method accounts for two factors that the Rational method does not: antecedent moisture conditions and initial abstraction,. Consideration of these factors tends to more fairly represent actual conditions than does the Rational method.

The SCS has mapped soils throughout the lower 48 United States and developed a system of soil types, ranked A through D, that relate to the CN in this equation. A review of the soil surveys of the Juneau and Bethel areas was made. The soil types in these areas have not been classified within this system. CN numbers were estimated, based on soils descriptions and their distributions in the developable areas. The CN is site specific and will vary from location to location within the municipality. This is especially true in Juneau; Bethel area soils are more homogenous. The soil type variability within the Juneau area will cause site specific runoff to be more variable than in Bethel. Antecedent moisture conditions are taken into account by assigning a higher CN; the higher CN is prescribed by the SCS and based on the CN for average conditions.

Despite these limitations regarding precipitation and CN values, we felt that TR-55 was the best available method to estimate the runoff from rainfall events. These limitations should be kept in mind, and the results from this method taken as relative rather than absolute values.

3.1.3.2 Snowmelt Runoff

Snow melt runoff is variable from year to year. Within a year, snow melt is highly variable in duration and volume. The length of the snow melt period varies, depending on daily and hourly temperatures, wind speed and direction, and the amount of snow on the ground. Although the amount of snow on the ground may influence the length of the snow melt period, it is not directly correlated to the amount of runoff, either over the snow melt period or on a given day, because of infiltration. If the ground beneath the snow is frozen, the amount of runoff will be greater. If freezing temperatures precede snow fall in the fall, the ground will freeze and stay frozen through the winter. Under these conditions, snow melt runs off rather than infiltrates, because the ground thaws after the snow melt. These factors influence snow melt runoff in each of the indicator communities to a different extent.

Snow melt runoff data was available for five urban basins in the Anchorage area, but none was available for Juneau or Bethel. The data for Anchorage (Brabets, 1987, and Billman and Bacon, 1990), collected during spring breakup periods, indicate that daily runoff rate lies generally in the range of 0.01 to 0.20 inches, but is variable from day to day, due to changes in temperatures, wind velocity, insolation, and other heat transfer components. The rate of runoff is also influenced by the amount of impervious area (including frozen ground as well as pavement and buildings), but this relationship has not been quantified. Snowmelt runoff does not occur until the snowpack is saturated. Saturation, or snow pack ripening, is generated by melting snow or rain trickling through the snowpack. Ripening may take a week or more, depending on the initial condition of the snowpack and the rate of snowmelt. Rainfall on a snow pack will accelerate the ripening process.

Since the day-to-day variability in temperatures during spring breakup is similar in all three municipalities, runoff rates for a specific series of days can be reasonably approximated using Anchorage data. A sequence of daily snow melt rates was derived from the Anchorage data, using a 30% impervious residential area, and applied to the land development scenarios for Anchorage, Bethel and Juneau. The length of the breakup period was determined by a combination of daily average temperatures above 32° F and the daily snow on the ground record for Bethel and Juneau. Both sets of snowmelt data (Billman and Bacon, 1990, and Brabets, 1987) showed an increase in snowmelt runoff from developed areas with higher imperviousness. A factor was applied to the assumed snowmelt rate from the 30% impervious area to account for this increase. This results in an equation of the form:

$$VOL = VOL_{30} *(1 + (PEIA - 30)*.03) \qquad (3)$$

where VOL = runoff, inches
VOL_{30} = runoff from 30% impervious site, inches
$PEIA$ = percent effective impervious area, expressed as a percent

This adjustment factor was based on basins varying from 30% to 70% impervious. Use of the factor for areas with imperviousness greater than 70% may overestimate the runoff; and for areas with less than 30% imperviousness, it may tend to underestimate the runoff.

Days of snow melt for winter months were defined based on the number of days the maximum temperature exceeded 32° Fahrenheit. No data were available for runoff from winter thaw events; but the initial spring snowmelt may be comparable to winter thaws. During the early part of the spring snowmelt, flow rates are in the range of 0.01 to 0.04 inches. These values were estimated from 1988 data (Billman and Bacon, 1990). Therefore, a constant snow melt rate was assumed on winter thaw days. Some winters may have extremely warm periods, causing greater snow melt runoff than this assumption covers, leading to an underestimation of snow melt. Conversely, thaw days with no runoff may also occur if there is little or no snowpack, and the constant rate assumption would overestimate runoff in that case.

3.1.4 TSS Loadings

TSS data is sparse in these areas of Alaska. Where it has been collected, it has rarely been correlated to antecedent rainfall conditions or to basin area. No daily data is available for an entire year at one site. The TSS data is most often collected in streams, which are not representative of developed conditions. Where it has been collected, sampling has occurred in the summer, or rainfall, months. Winter thaws and spring snow melt data are very limited.

TSS sampling data is expressed as a concentration of suspended particles per unit volume of water, generally, milligrams per liter (mg/l). TSS loadings represent the mass of suspended particles, generally represented by pounds per day or pounds per year. TSS loadings are obtained by multiplying the TSS concentration times the flow (times appropriate conversions factors for disparate units). Thus, a low flow with a high concentration can yield a similar load to a high flow with a low concentration.

3.1.4.1 Pre-Development TSS Loadings

Pre-development conditions in the three indicator municipalities span the spectrum from bare ground to natural undisturbed vegetation. The guidance manual specifying the New Development Management Measure (EPA, 1993) describes pre-development it as follows:

> " ...the term pre-development refers to the sediment loadings and runoff volumes/velocities that exist onsite immediately before the planned land disturbance and development activities occur. Predevelopment is not intended to be interpreted as that period before any human-induced land disturbance activity has occurred."

It goes on to say that

> "... management measure option II.A.(1)(b) is not intended to be used as alternative to achieving an adequate level of control in cases where high sediment loadings are the result of poor management of developed sites e.g. ... sites where land disturbed by previous development was not permanently stabilized."

From this, it appears that management measure II.A.(1)(a), the 80% removal measure, is applicable to bare or unstabilized sites and that management measure II.A.(1)(b) is more likely to be applied to sites that were stabilized or are in a naturally vegetated state before development. Therefore, pre-development TSS was estimated for natural or stabilized sites only.

TSS loadings for undeveloped conditions with natural vegetative cover were based on the Universal Soil Loss Equation (USLE). This equation takes the form:

$$A = R \times K \times LS \times C \times P \qquad (4)$$

where A = soil loss, tons/(acre)(year)
R = rainfall erosion index, in 100 ft - tons/acre x in/hr
K = soil erodibility factor, tons/acre per unit of R
LS = slope length and steepness factor, dimensionless
C = vegetative cover factor, dimensionless
P = erosion control practice factor, dimensionless

This method was originally developed to estimate the annual sediment yield from small cropland areas. It calculates annual soil loss in tons per acre, based on rainfall, soil erodibility, site slope and length, and cover and erosion control practices. Because this method is empirical and the parameters have been calibrated for agricultural conditions in the lower 48 United States, this method is not directly applicable for developed urban areas in Alaska. It is somewhat applicable for the "pre-developed" condition, assuming the effects of natural vegetation on soil loss in these indicator municipalities is similar to effects in the lower 48 states. Another drawback of the USLE is that it does not differentiate soil losses attributable to rainfall from those due to snow melt runoff. Since the equation is being used to estimate the annual load from soils with natural vegetative cover, it is reasonable to assume that snowmelt would not cause soil loss. Thus, the loads predicted by the USLE in this application represent pre-development TSS from rainfall events only but could reasonably approximate annual loads as well. This equation does not predict TSS concentrations or daily loads.

3.1.4.2 Post-Development TSS Loadings

TSS data from urban rainfall and snow melt runoff has been collected in the Anchorage area, but not for the same basins. This data were used to generate two relationships; one for rainfall and one for snowmelt. The rainfall-runoff-TSS load relationship is based on a regression equation using the parameters of runoff, drainage area, and percent effective imperviousness as independent variables. The snowmelt-TSS loading relationship uses consecutive thaw day as the independent variable.

The relationship between stormwater runoff and TSS concentrations is based on data from three urban basins in Anchorage and shows two distinct patterns. The first pattern is an initial peak of sediment concentration at the beginning of the storm and then a rapid decrease. The other pattern shows sediment concentrations following the fluctuations of the storm's runoff. These patterns reflect two TSS mobilization mechanisms. An initially high intensity storm mobilizes loose sediment readily. This observation follows from the USLE theory. A low intensity storm mobilizes sediment at a lower but more constant rate as the sediments are wetted and loosened over the course of the storm. It is reasonable to assume that the high intensity storm mobilizes particles of larger diameter, but it is not known whether the distribution of particle size in the TSS between the two storm types is significantly different.

Recognizing these limitations, a relationship was established between total storm runoff and TSS load. Regression techniques applied to data from these three basins were used to calibrate an equation that calculates estimated TSS loads based on the runoff volume, drainage area, and percent of effective imperviousness for a given basin (Brabets, 1987). The equation is of the form:

$$SSED = 42.6 * (VOL)^{0.90} (DA)^{1.01} (PEIA)^{0.71} \qquad (5)$$

where SSED is suspended sediment load, in pounds
VOL is volume of runoff, in inches
DA is drainage area in acres
PEIA is percent effective impervious area

This equation is considered to have a high standard error of estimation. However, it is used here, where no other information is available. It has been calibrated for basins of less than 38 acres that have effective imperviousness less than 70%, for storm rainfall events that are less than 0.5 inches.

Since rainfall patterns are expected to be quite similar for Anchorage and Bethel, the calibrated equation was used for predicting TSS loads in Bethel. This equation is limited to use on rainfall events of less than 0.5 inches. Even though this limitation is exceeded in Juneau, the application of this equation led to fairly reasonable TSS loadings for Juneau, so it was used for Juneau as well. There is no data with which to judge the accuracy of these estimates.

During snowmelt, mean TSS concentrations are typically higher than for rainfall runoff. Data from Chester Creek (Brabets, 1987) indicates that TSS concentrations in urban snowmelt can be 16% to 400% higher than in rainfall runoff.

Spring thaw TSS concentrations for two urban basins showed two concomitant patterns: a diurnal fluctuation and a trend through the snow melt period (Billman and Bacon, 1990). On a daily basis, suspended sediment concentrations peak in the afternoon with peak discharge (Brabets, 1989). Through the month (more or less) of the snow melt period, the daily concentrations are initially quite high and then decrease. Therefore, a relationship between day of snowmelt and runoff was developed based on 1988 data from two basins. It is of the form:

$$VOL = 215 - 5.48(DAY) \tag{6}$$

where VOL = runoff, in
DAY = day of snowmelt period

The constants in this equation are calibrated to 1988 data only. These constants vary from location to location and year to year, but the downward trend was verified by the Chester Creek data (Brabets, 1987). The relationship between concentration and day of the snowmelt period was assumed to be the same for thaw periods during winter months. The magnitude of the concentrations, however, was assumed to vary over the winter. Because the snowpack tends to accumulate sand and precipitated airborne materials over the course of the winter, TSS concentrations are expected to be highest in the spring and lower during an early winter thaw. Thus, for example, November thaw was assumed to exhibit TSS concentrations similar to those on day 25 of the spring thaw. The concentrations were multiplied times the flow to obtain TSS loads.

These snow melt patterns were considered to be similar in all three municipalities, although the magnitudes of concentrations vary. In Bethel where there is little street sanding, the snow melt concentrations were assumed to be half of those in Anchorage. In Juneau, the Anchorage concentrations were used.

3.1.5 Summary of Derivation Methods

A summary of the methods used for each location is shown in Table 1. Details regarding the development of the snow melt and rainfall runoff and TSS loading for each community are given in the following descriptions.

Table 1
Summary of Derivation Methods for Runoff and TSS Loadings

Variable	Rainfall	Spring Breakup Snowmelt	Winter Thaw Snowmelt
Anchorage			
Runoff	Equation (1)	Snowmelt runoff rates from Anchorage basins with Equation (3)	flat 0.03' rate
Pre Development TSS Loading	Equation (4)	none	none
Post Development TSS Loading	Equation (5)	Equation (6) for concentration; concentration x flow for load	Equation (6) for concentration; concentration x flow for load
Bethel			
Runoff	Equation (2); CNs for D soils	Snowmelt runoff rates from Anchorage basins with Equation (3)	flat 0.03" rate
Pre Development TSS Loading	Equation (4)	none	none
Post Development TSS Loading	Equation (5)	Equation (6) for concentration; concentration x flow for load	Equation (6) for concentration; concentration x flow for load
Juneau			
Runoff	Equation (2); CNs for C soils	flat 0.03" rate	flat 0.03" rate
Pre Development TSS Loading	Equation (4)	none	none
Post Development TSS Loading	Equation (5)	Equation (6) for concentration; concentration x flow for load	Equation (6) for concentration; concentration x flow for load

Equation 1 $VOL = 0.39 * (RF)^{1.10} (DA)^{0.14} (PEIA)^{0.38}$

Equation 2 $Q = \frac{(P-.2*S)^2}{(P+.8*S)}$

Equation 3 $VOL = VOL.3 *(1 + (PEIA - 30)*.03)$

Equation 4 $A = R \times K \times LS \times C \times P$

Equation 5 $SSED = 42.6 * (VOL)^{0.90} (DA)^{1.01} (PEIA)^{0.71}$

Equation 6 $VOL = 215 - 5.48(DAY)$

3.1.6 Land Development Scenarios

The development scenarios outlined for each municipality are those that can reasonably be expected to occur. An implicit assumption is that there is no runoff into these sites that must be treated. It is assumed that the stormwater control practices will be implemented by the developer of the site as part of site development. These construction costs and the annual and periodic maintenance costs will be passed along to the buyers or leaseholders. Although there may be some component of municipal involvement for maintenance, we assumed that the municipality would recoup the cost of this from the property owners.

For single family residential development, density was taken as four houses per acre. Of the land available, 90 percent would be used for housing and 10 percent for roads and other infrastructure, not including the stormwater control. Thus for a 5-acre residential development size, 18 houses are expected.

Commercial development was assumed to be retail stores. The building size was assumed to be one-third of the impervious area of the site. The other two-thirds would be paved.

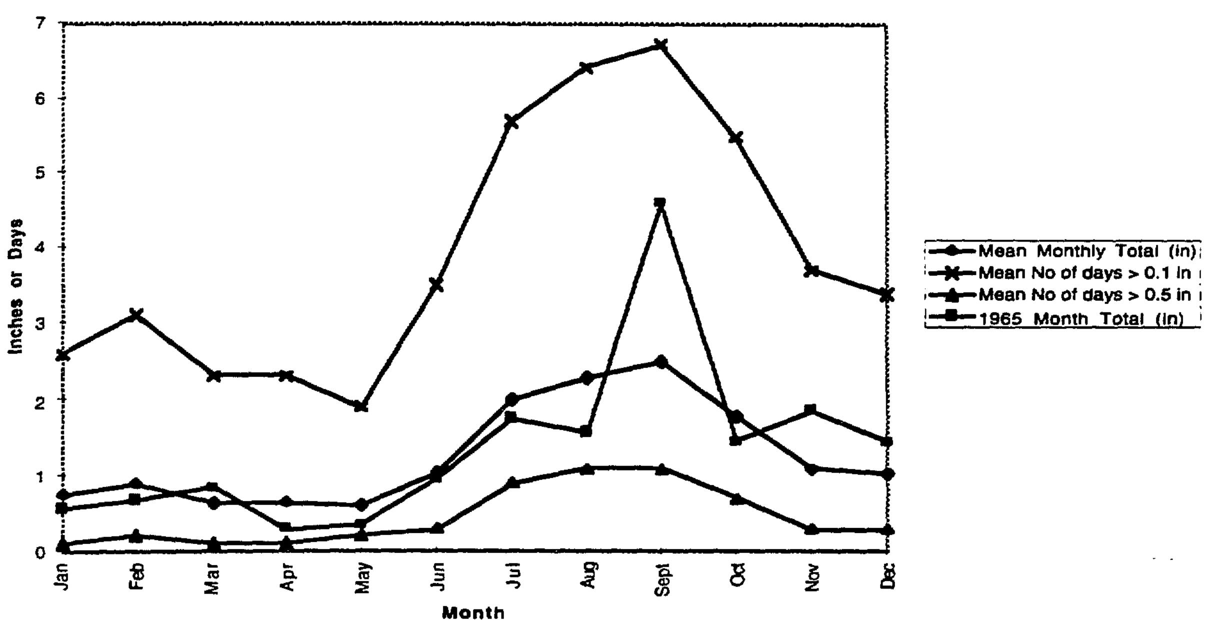
Industrial development was assumed to be equipment yards and warehouses. The building size was assumed to be one-half of the impervious area of the site. The other one-half would have equipment or covered storage.

3.2 ANCHORAGE

3.2.1 Rainfall

Anchorage precipitation averages 15.3 inches. TP 47 gives the 2-year/24-hour storm for Anchorage as 1.5 inches (Miller, 1963). The Municipality of Anchorage (MOA) uses 0.66 inches for a 2-year/6-hour event. MOA has not established a 24-hour event for any return period. Based on the depth of the 2-year/6 hour storm, however, the 2-year/24 hour storm event would likely be less than 1 inch. The monthly rainfall distribution is shown in Figure 2. This figure shows that the peak precipitation period is in the months of July through September. Rainfall greater than 0.5 inches occurs approximately 5 days a year.

Figure 2
Anchorage Mean Monthly Precipitation Distribution - 1923-1984 and 1991



Source: Leslie, 1986 and NOAA, 1965

3.2.2 Runoff

The Anchorage spring break up period is generally from mid March through mid April. Summer rains occur from the end of April through the middle to end of October. A daily runoff relationship for snow melt and for rainfall was developed for Anchorage, on a depth per unit area basis. The rainfall runoff relationship was developed on Chester Creek by the USGS (Brabets, 1987). The snow melt relationship was based on data from two residential basins and adjusted for percent imperviousness.

3.2.3 Soils and Drainage Conditions

Anchorage lies in a gently sloping bowl, although some developable land is located up stream and river valleys. The soils in the Anchorage area are glacial till. Some sites are on gravel or sand where the soils are highly permeable, but the majority of developable sites will be on relatively impermeable soils or near surface bedrock. The developable areas are drained by well defined creeks.

3.2.4 TSS

Total suspended solids data has been collected by the United States Geologic Survey (USGS) from 6 creeks in the Anchorage area . Most of the Anchorage area USGS data is based on stream sampling, which includes base flow, and generally represents runoff from several land use categories. One USGS report (Brabets, 1987), however, presents rainfall and snow melt runoff data from one commercial and one residential basin, and some in-stream data from an undeveloped basin. Snow melt data has been collected from two residential basins by the Municipality of Anchorage (Billman and Bacon, 1990).

Pre-development TSS loading for Anchorage was based on the Universal Soil loss equation.

Post-development TSS loading for Anchorage was based on the TSS-runoff relationship developed by the USGS (Brabets, 1987).

3.2.5 Expected Site Development Types

According to the MOA Department of Community Planning and Development (Weaver, 1995), Anchorage residential development is generally in the 2.5 to 5 acres range; a 40 acre site is considered large. Commercial site sizes are dictated by the amount of parking and percentage of landscaping required. Industrial sites are generally graveled. Assumed land uses and types are as follows:

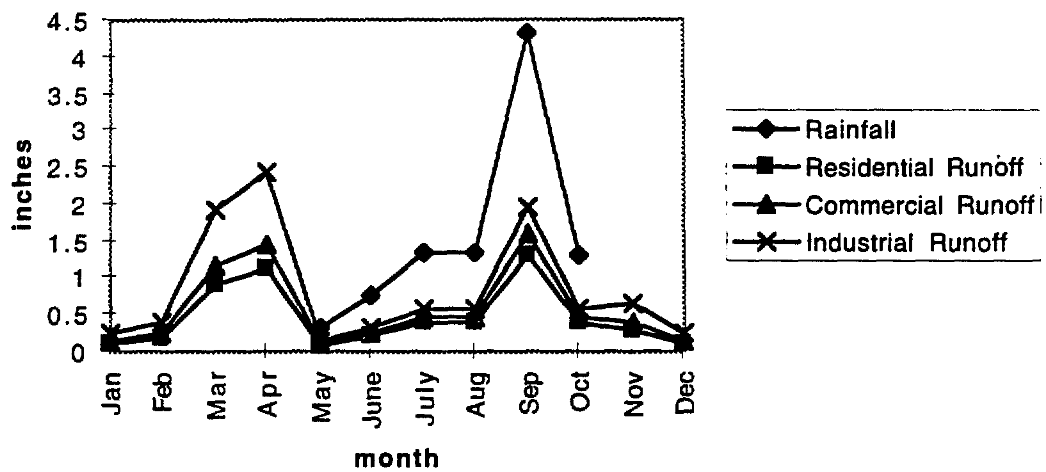
Residential	5 ac	4 houses per acre	38% impervious
Commercial	10 ac	123,000 sf retail store	85% impervious
Industrial	10 ac	109,000 sf warehouse/office	50% impervious

3.2.6 Typical Year

The Municipality of Anchorage has identified 1965 as its typical rainfall year (Wheaton, 1995). The snow melt runoff pattern for March and April, 1988, were used to simulate runoff. Winter thaw periods in the months of November through February were based on the number of days that, on a long-term average basis, the maximum daily temperature exceeded 32° F. During the winter thaw days, the number of thaw days per month was reduced by two, to account for the time it would take for the snowpack to ripen before runoff occurs.

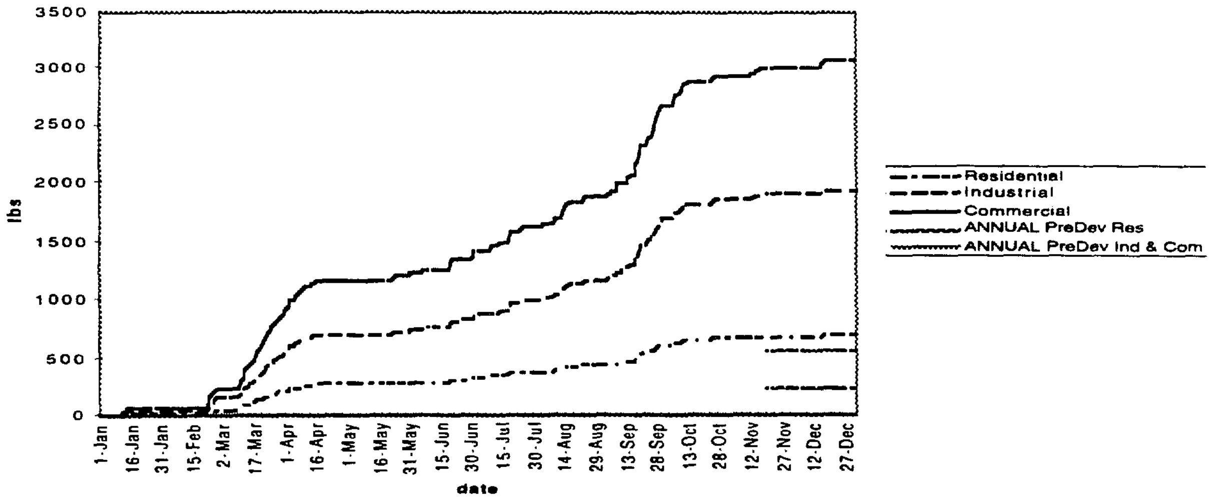
The rainfall-runoff pattern for Anchorage for the typical rainfall year is shown in Figure 3. Two runoff peaks, one in April and one in August, illustrate the bimodal runoff, from snowmelt and rainfall.

Figure 3
Anchorage Monthly Rainfall-Runoff Distribution for Typical Year



The cumulative TSS loading for the typical Anchorage year is shown in Figure 4. This figure shows the loadings due to runoff from development for each land use category. It also shows the total annual predevelopment load from each of the land use categories on the right side of the graph.

Figure 4
Cumulative Pollutograph for Anchorage for Typical Year



A summary of the hydrologic characteristics of each land development scenario is shown in Table 2.

Table 2
Hydrologic Characteristics of Each Land Development Scenario for Anchorage

			Land Use Type		
Variable	**Condition**	**Units**	**Residential**	**Industrial**	**Commercial**
Area		acres	5	10	10
% Impervious		%	38	50	85
Rainfall (May - Sept)		inches	9.45	9.45	9.45
Rainfall Runoff Depth	Pre Development	inches	1.01	1.01	1.01
	Post Development	inches	2.81	3.43	4.20
Snowmelt Runoff Depth	Pre Development	inches	0.35	0.35	0.35
	Post Development	inches	2.74	3.53	5.85
TSS Loadings	Annual Pre Development	lbs	240	560	560
	Annual Post Development	lbs	699	1942	3322
	Summer Post Development	lbs	338	992	1734
Removal Required for Pre=Post Conditions - Summer		%	29%	44%	68%
Median TSS Concentrations	Annual Post Development	mg/l	128	148	187
	Summer Post Development	mg/l	131	157	224
Maximum 6-hr flow	Summer Post Development	cfs	0.17	0.43	0.52
Median 24-hr flow	Summer Post Development	cfs	0.01	0.02	0.03

3.2.7 Local Regulations

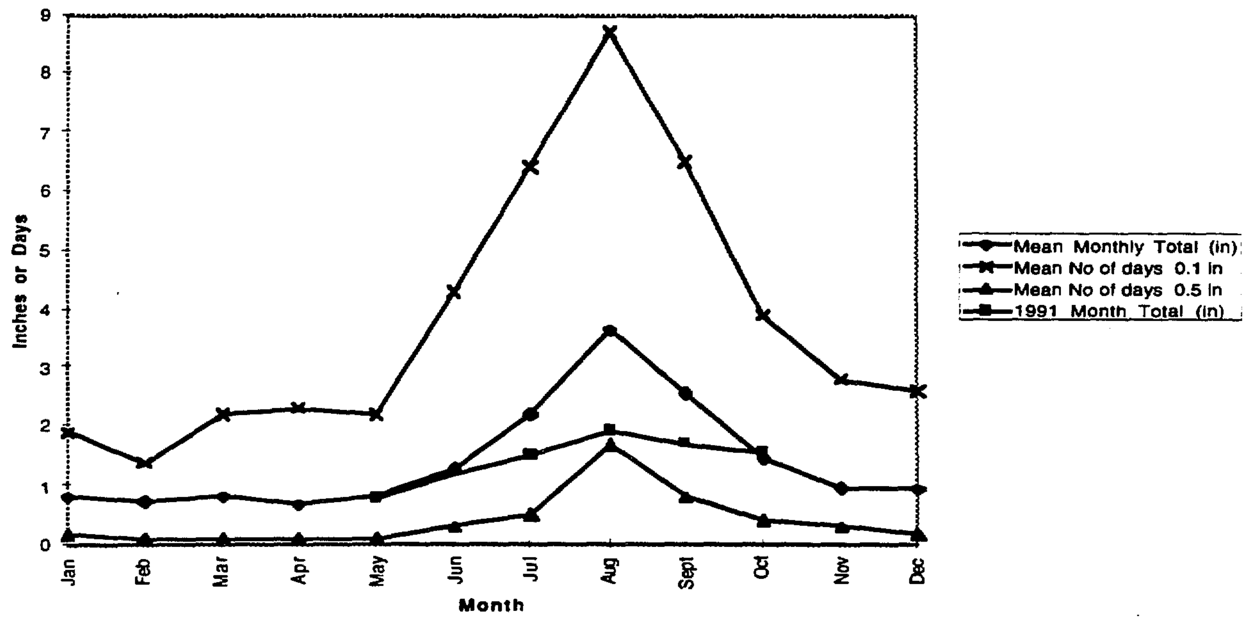
The population of Anchorage is greater than 100,000 so the MOA must comply with the National Pollution Discharge Elimination System permit requirements for stormwater runoff. In the course of applying for this permit, the MOA has modified its Municipal Code to implement regulatory control over stormwater discharge. In particular, the MOA has identified TSS as a pollutant for which it can require treatment or removal. The MOA has not established performance objectives for stormwater control and currently defers to the Alaska Department of Environmental Conservation (ADEC),which is the agency that can legally enforce its own performance objectives. In the interim, until the MOA establishes performance criteria, it will not issue a developer the authority to proceed without review by the state.

3.3 BETHEL

3.3.1 Rainfall

Bethel's annual precipitation is 16.9 inches. The 2-year/24-hour storm for Bethel is 1.5 inches (Miller, 1963). The rainfall distribution is shown in Figure 5. The highest precipitation occurs in August, and less than 5 days a year have rainfall depths greater than 0.5.

Figure 5
Bethel Mean Monthly Precipitation Distribution - 1923-1984 and 1991



Source: Leslie, 1986 and NOAA, 1991

3.3.2 Runoff

The TR-55 method was used to generate runoff from rainfall events in Bethel. Since the majority of rainfall is of low intensity, this method predicts very low runoff. In Bethel, total snowfall is somewhat less than Anchorage. Snowpack is also smaller than Anchorage, due to wind effects. Both of these factors lead to a shorter snow melt runoff period than Anchorage in general. Colder temperatures in April cause the snow melt period to occur later than in Anchorage.

3.3.3 Soils and Drainage Conditions

Bethel is located on the banks of the Kuskokwim River in southwestern Alaska. Bethel's soils are predominantly silts underlain by permafrost and are generally impermeable. This, and the lack of relief in area, create standing water following rainfall and snow melt events. Consideration for permafrost conditions has necessitated the construction of elevated roadways and above ground utilities. Scraping and grading of sites is generally limited to work on the constructed pads. Only one five mile road is paved; the rest are gravel or native soil. Very little, if any, sand is applied to the streets in the winter. Consequently, the primary source for sediment loading is erosion of the roadways and embankments. The primary stormwater structures are ditches and culverts. Most of the drainage is diffuse, with only one well defined creek running through the town.

3.3.4 TSS

There is no suspended sediment data for the Bethel urban area. Suspended sediment data is available for the Kuskokwim River, but this data is not representative of urban runoff TSS.

Pre-development conditions were estimated based on the USLE. A generalized regional analysis indicates that non glacial streams in the region probably do not normally exceed 100 mg/l in suspended sediment in the summer (Feulner, 1972).

The post development TSS loading for the Bethel area was assumed to be half the rate of the Anchorage area for snow melt runoff. In Bethel, roads are not typically sanded in the winter and streets and parking lots are not typically paved.

3.3.5 Expected Site Development Types

Bethel residential development is generally in the 2.5 to 5 acres range. The minimum lot size is 9,000 square feet. Commercial site sizes are small, generally accommodating such individual enterprises as a store or a bed-and-breakfast. No new industrial sites are likely to be developed; most industry is maritime and operates off-shore, on the Kuskokwim River. No street or parking lot paving is required, so the percent impervious is lower than that in more urban communities.

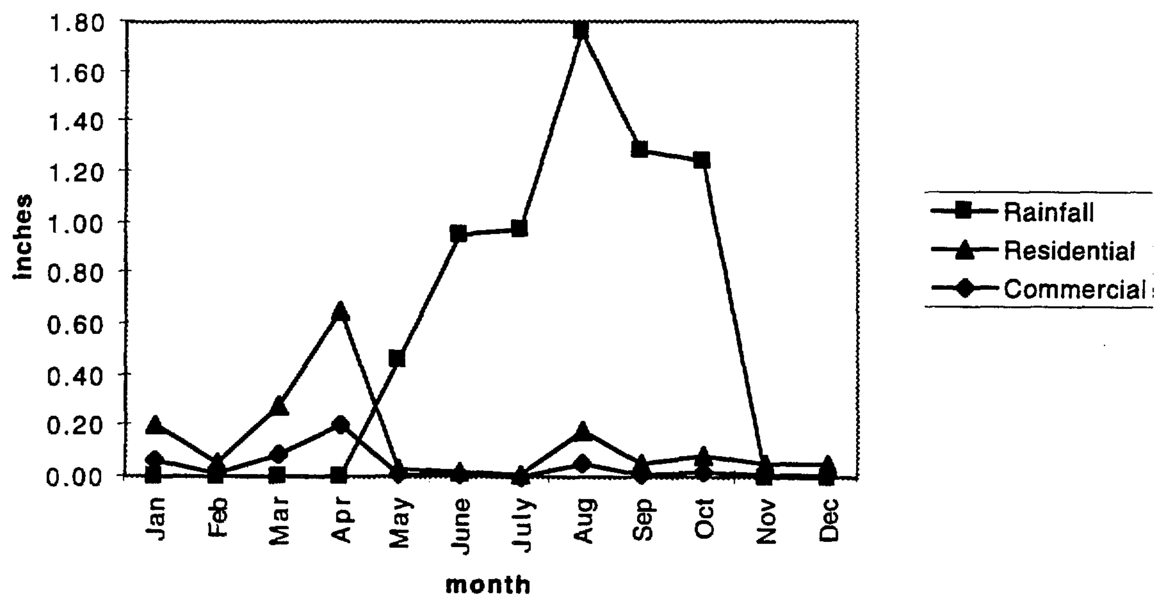
Residential	5 ac	4 houses per acre	25% impervious
Commercial	2 ac		40% impervious
Industrial	not anticipated		

3.3.6 Typical Year

1991 was identified because of its near normal annual precipitation and average March 31 snowpack. The March 31 snowpack was used as an indicator of the snow melt season, and to evaluate if the chosen year were typical or not. Rainfall and thaw events were taken from the climatological record for the year. The 2-year/24 hour rainfall was not exceeded on any day in 1991.

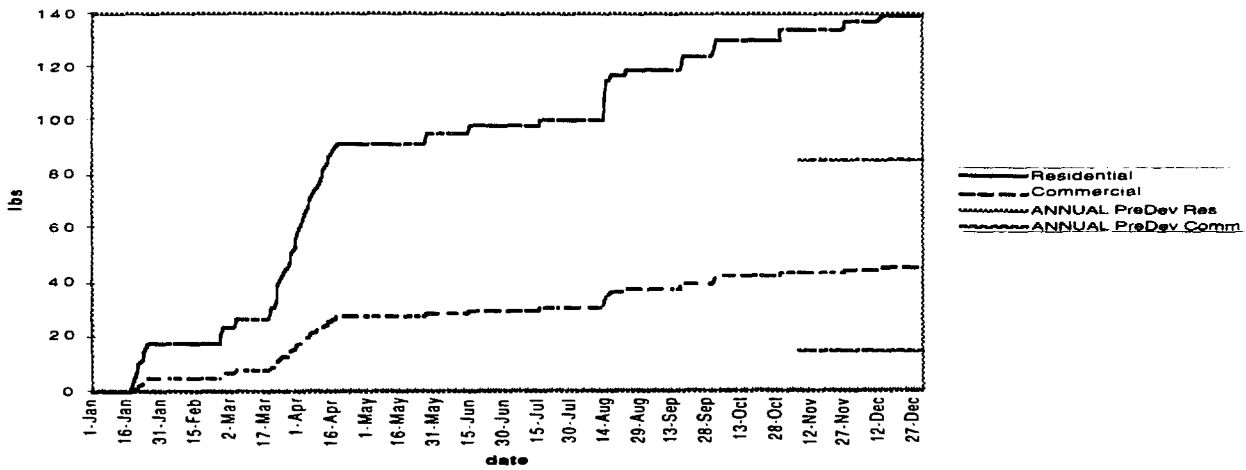
The runoff pattern for Bethel is shown in Figure 6. Two peaks, one in April and a smaller one in September, illustrate the runoff from snowmelt and rainfall.

Figure 6
Bethel Monthly Rainfall-Runoff Distribution for Typical Year



The cumulative TSS loadings for the typical Bethel year are shown in Figure 7. This figure shows the loadings due to runoff from development for each land use category. It also shows the total annual predevelopment load from each of the land use categories on the right side of the graph.

Figure 7
Cumulative Pollutograph for Bethel for Typical Year



A summary of the hydrologic characteristics of each land development scenario is shown in Table 3.

Table 3
Hydrologic Characteristics of Each Land Development Scenario for Bethel

			Land Use Type	
Variable	**Condition**	**Units**	**Residential**	**Commercial**
Area		acres	5	2
% Impervious		%	25	40
Rainfall (May - Sept)		inches	6.67	6.67
Rainfall Runoff Depth	Pre Development	inches	0.03	0.03
	Post Development	inches	0.39	0.55
Snowmelt Runoff Depth	Pre Development	inches	0.24	0.24
	Post Development	inches	1.29	1.97
TSS Loadings	Annual Pre Development	lbs	85	15
	Annual Post Development	lbs	140	45
	Summer Post Development	lbs	42	16
Removal Required for Pre=Post Conditions - Rainfall		%	-100%	8%
TSS Concentrations	Annual Post Development	mg/l	81	81
	Summer Post Development	mg/l	107	140
Maximum 6-hr flow	Rainfall Post Development	cfs	0.13	0.03
Average 24-hr flow	Summer Post Development	cfs	0.003	0.001

Calculated TSS loadings in Bethel decreased under developed conditions. We believe this would not be the case, for two reasons. A good cover of natural vegetation in the predevelopment conditions limit sediment loss. Developed conditions generally involve pad or elevated road construction, on which both the side slopes and horizontal surfaces are generally more vulnerable to erosion than predevelopment conditions. The predevelopment loads are most likely lower than those predicted by the USLE, which is especially sensitive to rainfall energy and the slope of the site. The post development loads are probably underestimated. Even though the sites have low percentages of imperviousness, the native soils are also highly impervious, as well. Because of the lack of data for Bethel with which to verify these results, they should be considered with skepticism. They do not provide a strong basis for development of target removal levels of TSS. However, because of other site specific conditions, no BMPs that can be designed to meet targeted removal levels are practical for Bethel.

3.3.7 Local Storm Drainage Regulations

Bethel has a Coastal Management Plan, which requires a review of subdivision plats. The municipal ordinance requires that drainage channels on private property be preserved and requires the installation of culverts where these channels are crossed by driveways or roads. There are no minimum landscaping requirements for commercial or industrial development, although the lots have minimum setbacks.

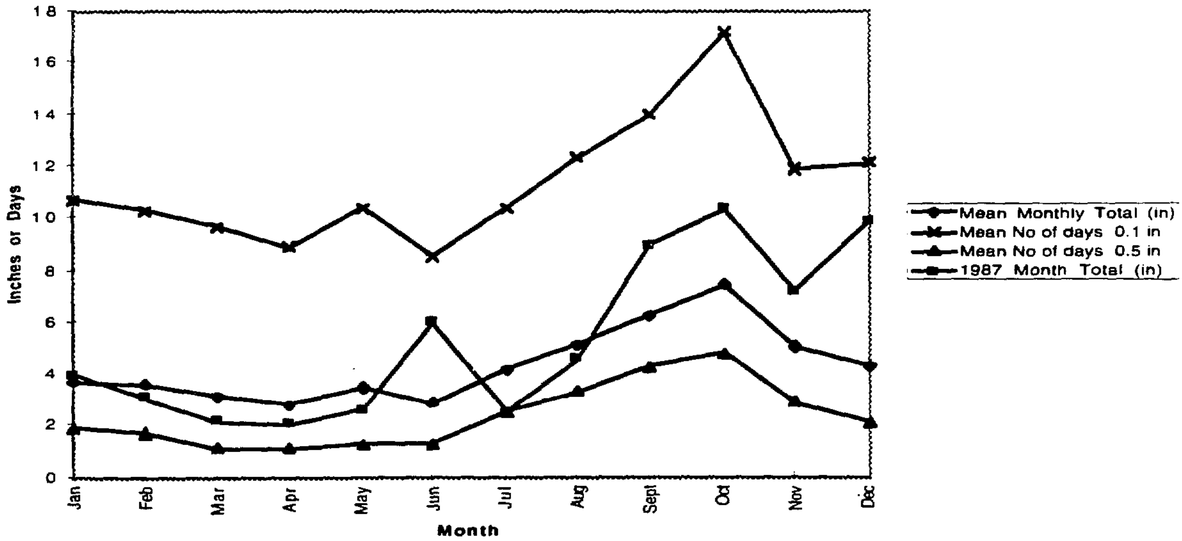
3.4 JUNEAU

3.4.1 Rainfall

Annual rainfall in southeast Alaska is much greater than in south-central or western Alaska. Juneau's climate is typically much rainier than either Bethel or Anchorage, but is highly variable even within the developed area of the City and Borough of Juneau (CBJ). The average annual rainfall in downtown Juneau (90 inches) is nearly twice that at the airport (52 inches). Data from the weather station at the airport were used in this study, because published records were more complete in recent years. In addition, new development is more likely to occur north of town than in the town proper. Use of the airport data will lead to an underestimation of the runoff, and therefore TSS, in some parts of Juneau. The 2-year/24-hour storm for Juneau is 3.0 inches (Miller, 1963).

The rainfall pattern for the airport weather station is shown in Figure 8. The maximum precipitation occurs in October. Precipitation exceeds 0.5 inches on 28 days a year. Although the shape of these curves is similar for the downtown weather station, the magnitude, both in inches and in days of exceedence is higher. There are 61 days a year when precipitation exceeds 0.5 inches.

Figure 8
Juneau Mean Monthly Precipitation Distribution - 1949-1984 and 1987



Source: Leslie, 1986 and NOAA, 1987

3.4.2 Runoff

The TR-55 method was used to generate runoff from rainfall events in Juneau. Rainfall tends to persist over consecutive days; so adjustments were made (to the assumed CN) to account for antecedent moisture conditions, which generally result in higher runoff.

Juneau's snow melt events include more frequent winter thaw events, including winter rains and earlier spring snow melt events than south-central or western Alaska. Some Juneau winters are dominated by rainfall runoff events, rather than snow and thaw events..

3.4.3 Soils

The high relief of the Juneau area has led to development along the coast and up stream and river valleys. The soils in the flood plains of these streams is silty. Soils on the uplands are either thin, underlain by bedrock or thicker glacial till deposits, which are firm and compact. Although there are tracts of well drained soil, the soil conditions generally impermeable. Storm runoff in developed areas is handled by a combination of underground storm sewers, ditches, and culverts. The developed areas are drained by creeks.

3.4.4 TSS

Total suspended solids data has been collected by the United States Geologic Survey (USGS) from creeks in the vicinity of Juneau. The TSS data collected from these streams is associated with mining activity and is not applicable to this study because the sites are much higher in elevation than the area where development may occur. Rainfall and snowmelt runoff conditions in southeastern Alaska are strongly affected by elevation, which reflects both orographic and temperature effects. The Alaska Department of Environmental Conservation (Richards, 1993) presents stream water quality data for 15 streams and rivers in the Juneau area. This data does not include the drainage area above the sampling point, instantaneous stream flow, or antecedent rainfall or snow melt conditions. This data can provide general ranges for the summer months.

The rainfall period was taken as the months of February through October. A TSS loading based on the Anchorage area runoff relationship was used. The snow melt runoff and TSS loading developed for Anchorage was used for winter thaw periods.

3.4.5 Expected Site Development Types

According to the CBJ's Department of Planning, Juneau's new development is generally characterized as in-filling. Its residential development is generally in the range of 5 acres range. A typical commercial site size is 15 acres. Industrial sites are generally graveled.

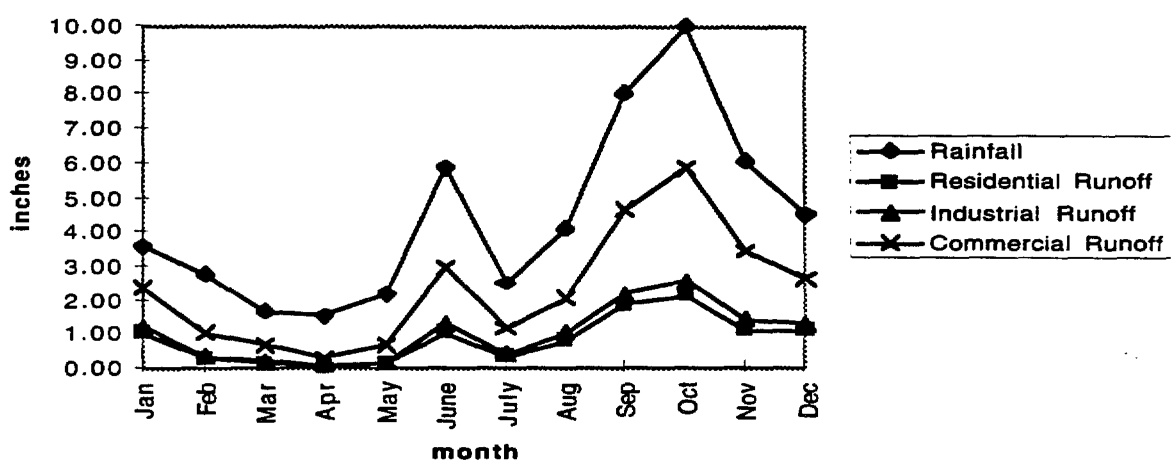
Residential	5 ac	4 houses per acre	40% impervious
Commercial	15 ac	retail store	85% impervious
Industrial	20 ac	218,000 sf warehouse/office	50% impervious

3.4.6 Typical Year

For Juneau, 1987 was identified as the year with total rainfall closest to the long term average. However, the winter snowfall was below average this year, and the winter temperatures above average. This led to a higher percentage of the runoff due to rainfall, with consequently lower TSS concentrations through the winter.

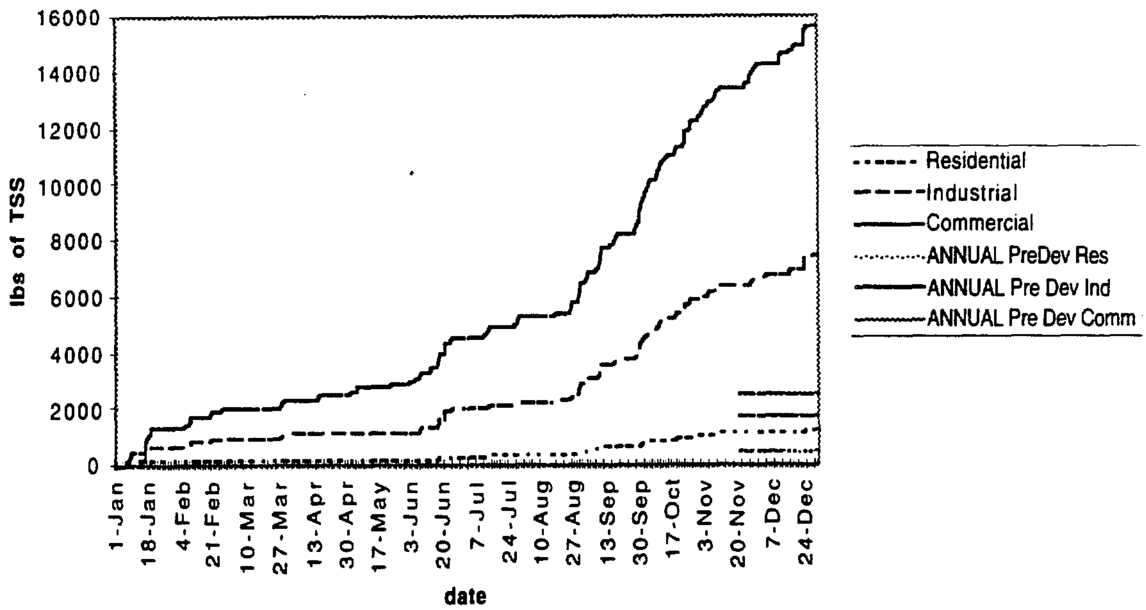
The runoff pattern for Juneau is shown in Figure 9. Two runoff peaks, in June and October, illustrate the runoff from rainfall.

Figure 9
Juneau Monthly Rainfall-Runoff Distribution for Typical Year



The cumulative TSS loadings for the typical Juneau year are shown in Figure 8. This figure shows the loadings due to runoff from development for each land use category. It also shows the total annual predevelopment load from each of the land use categories on the right side of the graph.

Figure 10
Cumulative Pollutograph for Juneau for Typical Year



A summary of the hydrologic characteristics of each land development scenario is shown in Table 4.

Table 4
Hydrologic Characteristics of Each Land Development Scenario for Juneau

			Land Use Type		
Variable	Condition	Units	Residential	Industrial	Commercial
Area		acres	5	20	15
% Impervious		%	40	50	85
Rainfall (Feb-Oct)		inches	38.54	38.54	38.54
Rainfall Runoff Depth	Pre Development	inches	1.41	1.41	1.41
	Post Development	inches	6.59	8.17	19.18
Snowmelt Runoff Depth	Pre Development	inches	0.04	0.04	0.04
	Post Development	inches	0.67	0.82	1.36
TSS Loadings	Annual Pre Development	lbs	480	2500	1785
	Annual Post Development	lbs	1285	7351	17782
	Summer Post Development	lbs	879	5106	12544
Removal Required for Pre-Post Conditions - Summer		%	45%	51%	86%
Median TSS Concentrations	Annual Post Development	mg/l	127	157	214
	Summer Post Development	mg/l	133	163	222
Maximum 6-hr flow	Summer Post Development	cfs	0.53	2.40	3.10
Median 24-hr flow	Summer Post Development	cfs	0.01	0.03	0.05

3.4.7 Local Storm Drainage Regulations

Juneau has a Coastal Management Plan which includes stream setbacks. The CBJ is currently working with the ADEC on two streams in the borough that have been identified as impaired. Developers in the CBJ have been required by ADEC to install stormwater controls on their project, after site specific review.

3.5 LOCAL ECONOMIC CONDITIONS

The economic indicators for each community are summarized in the Table 5. The figures that were available included population, municipal full value determination, total municipal revenue, median annual household income, and median owned-house value. Population and tax base extend over several orders of magnitude, although household income and median home price indicators are comparable.

Table 5
Economic Features of Indicator Municipalities

Feature	Anchorage	Bethel	Juneau
Incorporation Type	Unified Home Rule Municipality	Second Class City	Unified Home Rule Municipality
Population	248,296	2,009	29,078
Area (sq mi)	1,698	44	2,594
Population Density (per sq mi)	146	46	11
Property Tax (mils)	16.23	none	14.02
Total Municipal Revenue	$790,239,935	$9,729,980	$121,312,436
Municipal Full Value Determination (tax base)	$12,295,898,030	$184,121,800	$1,765,984,100
Median Household Income	$43,946	$45,203	$47,924
Median Owned Home Price	$109,700	$82,000	$113,500

Source: Alaska Department of Community and Regional Affairs, 1995

4.0 MANAGEMENT PRACTICES

4.1 SURVEY OF APPLICABLE BEST MANAGEMENT PRACTICES

In the previous section, typical annual pre and post development TSS loads for coastal Alaska were estimated. In this section, methods for reducing the TSS loadings, known as best management practices (BMPs), in coastal Alaska are presented.

Although scores of best management practices have been recommended and used throughout the lower 48 states, Alaska's climatological conditions limit the applicability of many of them. We have completed a draft survey of potential BMPs for stormwater pollution prevention, with an extensive and thorough summary of their applicability to Anchorage conditions, for the Municipality of Anchorage (MW, 1994). That document and three sources (Scheuler, 1987, Scheuler, 1992, EPA, 1993) were reviewed for applicability to the municipalities and land development types targeted in this study.

Twenty best management practices (BMPs) are outlined on Tables 6 and 7. Table 6 includes 11 non-structural practices. Table 7 includes 9 structural practices This list has been developed to aid in the selection of Best Management Practices (BMPs) for new development projects in coastal Alaska, particularly for the scenarios used for the cost analysis in this study.

In the first column, a code indicating the function of the BMP is listed. The BMPs are arranged in the following categories:

Source	**BMPs Which Reduce Pollution at Their Source**
Erosion	**Erosion, Sedimentation and Drainage BMPs**
Vegetative	**Vegetative BMPs**
Retention	**Retention/Detention and Flow Regulation BMPs**
Filtration	**Filtration and Infiltration BMPs**

The second and third columns gives the name and a description of the BMP.

The fourth column describes site specific constraints, clarifies how the BMP may be applied and may mention unusual maintenance conditions (e.g. a BMP has a very short life even with proper maintenance).

The fifth through seventh columns gives a ranking for each municipality. The identified BMPs are ranked for their applicability to each of the three indicator municipalities and the land use scenarios developed for the cost analysis. The rankings are based on professional judgment, weighing such factors as:

- site size
- soil type
- slopes less than 5%
- maintenance requirements
- climatic conditions
- community acceptance
- constructibility in given community
- existing storm drainage infrastructure

The ranking for non-structural (NS) and structural (S) BMPs are separate, with 1 being the most effective in the given category for the given municipality. Entries of N/A indicate that the BMP would not be applicable to the municipality.

Table 6
Non-structural Best Management Practices

Function	Non-structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Source	Maintenance of urban runoff facilities	Ensure that all urban runoff facilities are operated and maintained properly. Maintenance should occur at regular intervals, be performed by one or more individuals trained in proper inspection and maintenance of urban runoff facilities, and be performed in accordance with the adopted standards of the State or local government (EPA, 1993).		1	1	1
Source	Setback distances near wetlands, waterbodies, and riparian areas	Setback distances should be determined on a site-specific basis since several variables may be involved such as topography, soils, floodplains, cut-and-fill slopes, and design geometry (EPA, 1993).	In level or gently sloping terrain, a general rule of thumb is to establish a setback of 50 to 100 feet from the edge of the wetland or riparian area and the right-of-way. In areas of steeply sloping terrain (20 percent or greater), setbacks of 100 feet or more are recommended. Right-of-way setbacks from major waterbodies (oceans, lakes, estuaries, rivers) should be in excess of 100 to 1,000 feet (EPA, 1993).	8	4	7
Source	Residential road and street planning	Plan residential roads and streets in accordance with local subdivision regulations, zoning ordinances and other local site planning requirements.	Narrower streets would reduce the quantity of runoff and accompanying pollutants.	10	6	6

Table 6
Non-structural Best Management Practices (cont.)

Function	Non-structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Source	Retain existing functions of wetlands and riparian areas	Do not alter wetlands or riparian areas to improve their water quality function at the expense of their other functions (EPA, 1993).	In general, the location of surface water runoff ponds or sediment retention basins in healthy wetland systems should be avoided (EPA, 1993).	11	2	11
Source	Sweep, vacuum, and wash parking lots	Sweeper technologies used in conjunction with other BMPs that are effective in trapping fine solids could improve downstream water quality (NVPDC, 1987).	Equipment types commonly used for street sweeping include abrasive brush and vacuum device sweepers. A newly developed helical brush sweeper that incorporates a steel brush with vacuum has been shown to be more effective at removing fine solids and is currently being evaluated (NVPDC, 1987).	2	N/A	2
Source	Preserve natural drainage features and natural depressional storage areas	Natural drainage features infiltrate and attenuate flows and filter pollutants. Depressional storage areas reduce runoff volumes and trap pollutants (EPA, 1993).		3	3	3
Source	Snow storage	Sites designated to keep melt water runoff from overloading streams with pollutants. New sites should provide containment and appropriate treatment (HDR and CH2M Hill, 1993).	Prevent dumping of accumulated snow into surface waters (EPA, 1993).	5	7	5

Table 6
Non-structural Best Management Practices (cont.)

Function	Non-structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Source	Alternative sanding practices	Apply sand in controlled amounts based on temperature and road conditions.		4	N/A	4
Erosion	Minimize imperviousness	Restrict paving and the use of non-porous cover materials in recharge areas (EPA, 1993).		9	N/A	10
Erosion	Reduce the hydraulic connectivity of impervious surfaces	Pollutant loading from impervious surfaces may be reduced if the impervious area does not connect directly to an impervious conveyance system (EPA, 1993).		7	N/A	9
Vegetative	Retain existing vegetation wherever feasible	Clear only those areas that are essential for completing site construction. Avoid disturbing vegetation on steep slopes or other critical areas. Route construction traffic to avoid existing or newly planted vegetation. Protect natural vegetation with fencing, tree armoring, retaining walls, or tree walls (EPA, 1993).		6	5	8

Table 7
Structural Best Management Practices

Function	Structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Vegetative	Vegetated filter strip	Low gradient area of land with vegetative cover that is designed to intercept runoff as overland sheet flow from upstream development (EPA, 1993).	In coastal Alaska, vegetated filter strips will be limited by a fairly short growing season and will not be effective during initial snowmelt.	2	4	2
Vegetative	Grassed swale	An earthen conveyance system in which pollutants are removed from urban stormwater by filtration through grass and infiltration through soil (Schueler, Kumble, and Heraty, 1992).	In coastal Alaska, grassed swales will be limited by a fairly short growing season and will not be effective during initial snowmelt.	4	3	4
Vegetative	Seeding and mulch/mats for side slope protection	Seeding with erosion protection blankets protects road and pad side slopes while the vegetation becomes established (EPA, 1993). Erosion protection blankets are tacked in place and can be made of straw, jute netting or nylon fiber. Seeds can be incorporated into the blanket to provide the necessary ground cover to curb erosion and aid plant establishment .		7	1	7
Vegetative	Vehicle surface preparation	On roads and in parking and storage areas where asphalt and concrete are too expensive, an alternative soil cap is beneficial to counter wind and water erosion.	Gravel caps are the prime example of this method. Permazyne, a chemical soil additive, is in the research stage in rural Alaska. Soil cement is an older technology that may serve this function.	6	2	6

Table 7
Structural Best Management Practices (cont.)

Function	Structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Detention	Extended detention pond	A pond which temporarily detains a portion of urban runoff for up to 24 hours after a storm, using a fixed orifice to regulate outflow at a specified rate, allowing solids and associated pollutants the required time to settle out. Normally dry between storm events and does not have any permanent standing water. Provides greater flexibility in achieving target detention times (EPA, 1993).		5	N/A	5
Detention	Wet pond (also called sedimentation basin)	A basin designed to maintain a permanent pool of water and temporarily store urban runoff until it is released at a controlled rate. (EPA, 1993).		1	N/A	1
Detention	Catch basin (water quality inlet)	In its simplest form, a catch basin is a single-chambered urban runoff inlet in which the bottom has been lowered to provide 2 to 4 feet of additional space between the outlet pipe and the structure bottom for collection of sediment. Several designs exist (EPA, 1993).		3	N/A	3
Detention	Catch basin with sand filter (water quality inlet)	A water quality inlet with a second chamber containing a sand filter to provide additional removal of finer suspended solids by filtration. The first chamber provides effective removal of coarse particles and helps prevent premature clogging of the filter media (EPA, 1993).		8	N/A	8

Table 7
Structural Best Management Practices (cont.)

Function	Structural BMP Name	BMP Description	Constraints, Applications, and Unusual Maintenance Conditions	Rank of Applicability to Anchorage	Rank of Applicability to Bethel	Rank of Applicability to Juneau
Infiltration	Porous pavement and permeable surfaces	A porous asphalt through which runoff is diverted into an underground stone reservoir, gradually exfiltrating out of the stone reservoir into the subsoil (EPA, 1993).		9	N/A	9

4.2 TYPE OF DEVELOPMENT AND BMP FOR EACH LAND USE

The II.A.(1)(a) management measures for controlling TSS in runoff from new development is expressed as 80% removal of TSS. The second management measure, prescribing that post development TSS load equal predevelopment loads, can also be expressed as a percentage, when the pre and post development loads are known. The percentage efficiency of the BMP is calculated by dividing the mass of settled TSS by the mass of the total incoming TSS. These percentages establish target levels of TSS removal.

Non-structural BMPs have proved effective in removing TSS, but cannot be managed to meet targeted removal levels. Vegetative structural BMPs have also proved effective, even in northern climates (Marshall, 1991), but cannot be designed to remove a targeted level of TSS. This is due both to lack of information to aid in developing design methods as well as the variability of performance in the field. Performance is highly dependent on proper construction and maintenance. The only structural BMPs that can be designed to targeted reduction levels include detention and infiltration methods.

Infiltration methods, which include retention facilities and infiltration structures, are not applicable in areas where soils are relatively impervious. This is always the case in Bethel, which has uniformly silty soils. It is the general case in Anchorage and Juneau. In Anchorage and Bethel, and to a lesser extent in Juneau, infiltration methods are only functional for the times of the year when they are neither covered by snow nor frozen. Because of these limitations they were not considered to be effective.

Detention methods detain storm water. While the water is detained, sedimentation occurs, which lowers the TSS concentration in the outflow. Gravity detention structures (those not requiring mechanical equipment such as pumps) require excavation in order for water to flow by gravity. In Bethel, construction requiring excavation is not feasible due to the high groundwater table and permafrost conditions. In Juneau and Anchorage, detention facilities, either water quality inlets or sedimentation basins, have been used on site specific bases. Since these are considered to prove more effective than infiltration methods, they were chosen for the cost analysis rather than infiltration methods.

Detention BMPs remove TSS by settling suspended particles. Under passive treatments (that is, with no chemical or physical controls), settling occurs by precipitation. Particle settling is influenced by three factors: settling velocity, flow rate and surface area of the detention facility. These factors are related by the following equation:

$$\frac{Q}{V_S} = A$$

where Q = flow rate, cfs
V_S = particle settling velocity, ft/sec
A = basin surface area, sq ft

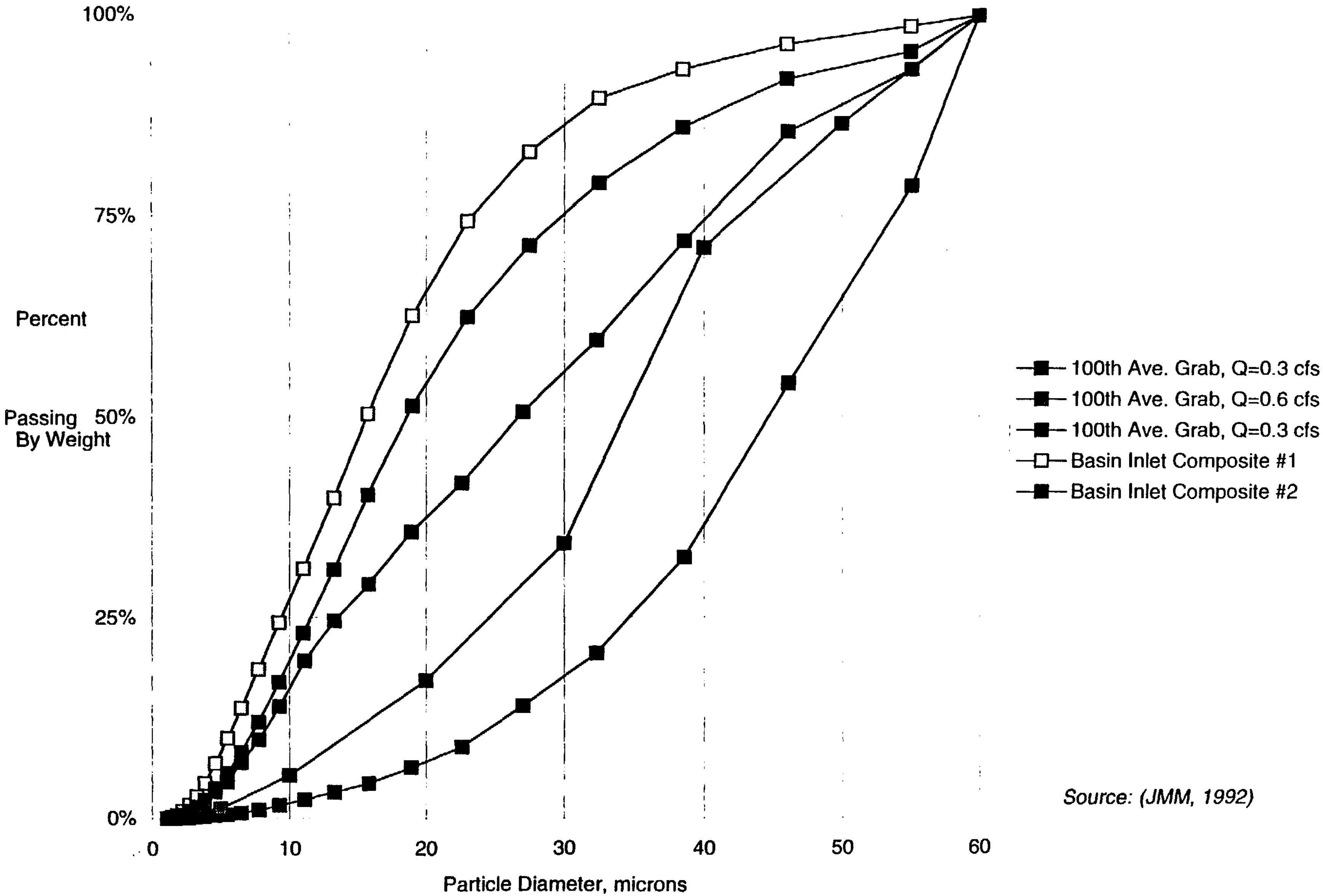
Settling velocity is dependent on water temperature and particle shape and diameter . The colder the water, the smaller the particle diameter, and the less spherical the particle, the slower the particle settles. The suspended particles that make up TSS vary in diameter and shape. Clay particles settle very slowly, if at all, because of their planar shape. Turbulence and wind action create conditions under which smaller particles do not follow this equation, because the lift forces counteract gravity and they cannot settle. Experience has shown that it is usually physically practical to design for removal of sands, but removal of silts and clays is likely to be physically prohibitive (Walesh, 1989). Clays and silts have particle diameters in the range of <2 microns and 2 to 50 microns, respectively. For purposes of this analysis, 10 microns was taken as the minimum diameter of a settleable particle.

Distribution of particle size within the TSS varies, depending on the sources of the TSS, such as local soils and road maintenance practices. The distribution also varies based on storm intensity; higher intensity rainfalls can mobilize larger particle sizes. (This follows from the Universal Soil Loss Equation). If all of the TSS particles are greater than 10 microns, a high removal efficiency can theoretically be achieved. Conversely, a large fraction less than 10 microns will place a lower limit on the sedimentation efficiency. It follows that the percentage of the TSS particles, by mass, greater than 10 microns, defines the upper level of removal efficiency that can be achieved.

Sediment sampling results are available from stormwater in the Anchorage area (JMM, 1992) and are shown in Figure 11. The Basin Inlet Composite #1 in Figure 11 represents the particle range of a number of composited samples. The percent of suspended sediment greater than 10 microns for Basin Inlet Composite #1 is 72%. Although the other samples show a higher percentage of particles greater than 10 microns, Basin Inlet Composite #1 represents the lower bound on the distribution. This 72% value, and the particle size distribution for these small diameter particles, compare favorably with the particle size distribution found in stormwater from nationwide sources (Pitt, 1985), where 78% of the particles were greater than 10 microns. As mentioned previously, rainfall intensity is one factor that determines TSS loading and it follows that higher intensity storms mobilize particles of larger diameter. Since rainfall in the Anchorage area is generally of lower intensity than the nationwide average, the slightly greater percentage of smaller diameter particles is reasonable. Therefore, this distribution was used in evaluating the expected efficiency of sedimentation basins in Anchorage. This distribution was also used to evaluate the efficiency of sedimentation basins in Juneau, because, even though the Juneau area experiences higher annual rainfall, its rainfall intensities are still lower than the nationwide norm. Because Bethel has uniformly silty soils, we would expect an even smaller percentage of particles greater than 10 microns.

Based on the particle size distribution, the best removal efficiency that can be expected in Juneau and Anchorage is 72%; and even lower in Bethel. Therefore, sedimentation basins will not meet the 80% target of management measure in II.A.(1)(a) in these locations in coastal Alaska. However, for five of the land development scenarios, reducing pre development loads to post development levels entails removal rates lower than 72%. For these scenarios, sedimentation basins were sized to meet the percent removal rates, and prototype sedimentation basins were designed. Cost figures have been calculated for these prototype basins.

Figure 11. Particle Size Distribution Analyses for Suspended Sediment in Storm Water



Quantifiable structural BMPs are not feasible for the residential or commercial land development scenarios in Bethel. The recommended control methods include gravel capping of parking areas and erosion protection on the side slope of pads. There is not enough data to determine whether these BMPs will achieve the targeted removal rates, but it is reasonable to assume a 50% removal rate.

Table 8 summarizes the target removal efficiency for each municipality and land use scenario under management measure II.A.(1)(b) for rainfall runoff events. There was no municipality in which 80% removal efficiency (management measure II.A.(1)(a)) could be achieved. The scenarios in which these target percentage removal levels were less than 72% were carried forward for cost estimates in Section 5.

Table 8
Summary of Target TSS Removal Percentages

Target Removal Efficiency (%) Required for Pre=Post Development (II.A.(1)(b)			
	Municipality		
Land Use	Anchorage	Bethel	Juneau
Residential	29	-100	45
Industrial	44	8	51
Commercial	68	NA	86

Costs were not developed for other removal scenarios for various reasons. Since none of the municipalities have specific local ordinances addressing TSS removal levels, no cost estimates were developed for meeting existing municipal ordinances. As mentioned previously, the effectiveness of non-structural measures cannot be quantified. Since non-structural measures cannot be recommended to meet the management measures, no cost analyses was performed. No industrial development scenario for Bethel was considered, because a new industrial site that could reasonably be expected to be developed could not be characterized. No cost estimates were developed for residential and commercial land development in Bethel, since there are no quantifiable BMPs that will work there. As discussed in Section 3.3.6, the TSS loading estimates made for pre and post development loads for Bethel are highly uncertain, so any costs developed based on the loading estimates would be ambiguous.

5.0 COST ESTIMATES

5.1 DESIGN CONSIDERATIONS FOR SELECTED BMP CONSTRUCTION AND MAINTENANCE

Sedimentation basins sizes were estimated for five of the scenarios based on rainfall runoff flows and TSS loading. The minimum pond surface area was calculated by an iterative technique. A pond surface area was assumed, and the mass of TSS removed by the pond for each storm in the typical year was calculated. The total mass removed from all rainfall runoff was divided by the total TSS for the rainfall season to obtain a summer removal percentage. When the removal percentage matched the level prescribed in Table 8 (the pre=post management measure), the pond surface area was established. In all cases, the calculated pond surface areas were too large to be incorporated into underground facilities, such as water quality inlets. Therefore, sedimentation ponds were chosen as the BMP for each scenario. Other design considerations, such as maximum side slopes and minimum storage volume for retained sediment, dictated a larger pond size in three out of the five cases. These considerations were included in the design on which cost estimates were based. Appendix B gives details of the assumptions and methodology used to determine the pond design for each scenario.

Table 9
Summary Pond Sizes

Land Use	Municipality							
	Anchorage				Juneau			
	Minimum Sedimentation Pond Size		Estimated Removal Efficiency		Minimum Sedimentation Pond Size		Estimated Removal Efficiency	
	Theoretical Surface Area	Practical Surface Area	Summer	Annual	Theoretical Surface Area	Practical Surface Area	Summer	Annual
		sq ft	%	%	sq ft	sq ft	%	%
Residential	90	1,300	72	44	450	1,300	66	55
Industrial	400	1,300	67	43	2,600	2,600	51	43
Commercial	1,600	1,600	65	42	NA	NA	NA	NA

Table 9 shows a summary of minimum pond sizes. The theoretical minimum pond surface area was calculated by the iterative technique described above. The practical pond surface area was determined by the geometry of the pond design criteria. The summer and annual percentage removal rates for the practical pond surface areas are also shown. The annual percentage removal rates were based on the assumption that the pond would be effective during 25% of the snowmelt runoff events in Anchorage and 50% of the snowmelt runoff events in Juneau. Although we feel these are reasonably conservative assumptions, there are no data to support them.

5.2 COST ESTIMATE FOR SELECTED BMPS

Cost estimates for storm water controls are presented in Table 10. The costs for stormwater controls included land costs and building and site development costs. The sum of these is the total capital cost (TCC). The costs for construction of the controls were based on a prototype sedimentation design, and unit prices for construction from Means Heavy Construction Cost Data. In addition, annual and periodic maintenance costs were estimated. The maintenance tasks were itemized and unit prices for these were taken from Means Heavy Construction Cost Data. The annual cost for development was estimated by annualizing the capital costs over 25 years at 10 percent interest rate. The total annualized cost (TAC) of the project includes both the annual maintenance costs and the annualized capital cost.

For prices taken from the Means Cost Data, the City Cost Index for Anchorage was used to adjust the unit prices for Anchorage. For Juneau, the 105 percent of the Anchorage City Cost Index was used.

These methods are consistent with the method used by the EPA in its economic analysis of coastal nonpoint source pollution controls. (EPA, 1992).

Table 10
Estimated Stormwater Control Costs

	Type of Land Use		Storm Water Controls				
Municipality	Project Size (ac)	Project Type	Total Capital Cost ($)	O&M Cost ($)	Total Annualized Cost ($)	Acres Required	Annual Cost per Developed Acre ($)
Anchorage	5	Residential(38%)	38,231	3,754	7,966	0.34	1,593
	10	Industrial(50%)	33,695	3,754	7,466	0.34	747
	10	Commercial(85%)	68,720	4,095	11,666	0.36	1,167
Juneau	5	Residential(40%)	38,782	3,936	8,208	0.34	1,642
	20	Industrial(50%)	39,472	5,402	9,751	0.43	488

5.3 MEASURES OF ECONOMIC IMPACT

To measure the control practices' economic impact on development activities, ratios of stormwater control costs to development costs without stormwater controls were computed, based on costs derived in Section 5.2. These ratios, consistent with the method used by the EPA (EPA, 1992), are described as follows:

Residential development

TCC/total land price
TCC/number of housing units / median home price
TAC/number of housing units / median annual mortgage
TAC/number of housing units / median household income

Commercial and Industrial development

TCC / Total development cost
TAC / Annualized development cost

Two costs were used to estimate capital development costs for commercial and industrial development, land costs and building and site development costs. Land prices were based on local knowledge. Building and site development costs were obtained from Means Building Construction Cost Data. The annual cost for development was estimated by annualizing the capital costs over 25 years at 10 percent interest rate.

Residential housing costs were based on tabulated data from the State of Alaska Department of Community and Regional Affairs (1995). This source reports median household income and the median value of owned homes. The annual mortgage payment was calculated from the owned home value, assuming a 15% down payment, an 8%, thirty-year note, and 10% for insurance and taxes.

The storm water control to development costs are shown in Table 11. Also included in Table 11 are the range of values for similar ratios as reported by EPA for control costs meeting both management measures. As pointed out in Section 5.1, no BMP controls are expected to treat storm water to the 80% removal level. Therefore, the costs and ratios presented here are for meeting the pre=post management measure only.

Table 11
Measures of Economic Impact

Single Family Residential					
Municipality	Project Type	TCC/House/Annual Mortgage (%)	TCC/Land Price (%)	TAC/House/ Household Income (%)	TCC/House/ House Price (%)
Anchorage	Residential	1.94	2.93	4.86	1.01
Juneau	Residential	1.90	2.97	4.84	0.95
National Range for Single Family		.31 - .93 %	3.7 - 8.6 %	.45 - 1.3 %	.16 - .32 %
Commercial and Industrial					
Municipality	Project Type	Capital Development Cost ($)	Annualized Capital Cost ($)	TCC/Capital Cost (%)	TAC/ Annualized Cost (%)
Anchorage	Industrial	9,090,613	1,001,495	0.37	0.75
	Commercial	15,219,444	1,676,697	0.45	0.70
Juneau	Industrial	18,654,687	2,055,151	0.21	0.47
National Range for Commercial Only				.49 - .67 %	.70 - .95 %
TCC - total capital cost for storm water control TAC - total annualized cost, including O&M, for storm water control					

As can be seen in Table 11, the measures of economic impact for stormwater controls on residential development are consistently high compared to the national range, except in the comparison with land values alone. For commercial land development, the economic impact ratios are within the national range. The residential economic indicators use the annual household income and mortgage expense of the eventual owners of the property. The commercial economic indicators only represent the cost of controls as a portion of the total development cost. The residential method more accurately reflects the market's willingness to pay than does the commercial method. In the commercial method, there is no way to determine if the incremental costs will still make the development an attractive one for investors or buyers. Therefore, even though the commercial economic indicators in Table 11 compare favorably with national averages (EPA, 1992), they do not reflect the true conditions that would determine whether the control measures are economically achievable.

Table 12
Unit Costs for Stormwater Controls

Municipality	Development Type	Area	TAC	Annual Load	Removal of Annual Load	Load Removed	Cost per Acre per Year	Cost per Pound Removed
		ac	$	lbs	%	lbs	$	$
Anchorage	Residential	5	7,966	699	44	308	1,593	25.90
	Industrial	10	7,466	1,942	43	835	747	8.94
	Commercial	10	11,666	3,322	42	1,395	1,167	8.36
Juneau	Residential	5	8,208	1,287	55	708	1,642	11.60
	Industrial	20	9,751	7,403	43	3,183	488	3.06

Table 12 summarizes the annualized unit costs of stormwater controls in cost per developed acre and cost per pound of sediment removed.

6.0 CONCLUSIONS

The 80% TSS removal standard cannot be reliably met in any of the three indicator communities by any BMP whose performance can be quantified. Since the only quantifiable BMPs that will work rely on settling and the fraction of settleable solids is less than 80%, there is no way to improve the removal rate by BMPs. The methods for removing the remaining unsettleable fraction involve chemical or physical treatment, such as employed for drinking water supplies. These methods are much more expensive than BMPs and would fail the economic indicator tests for developments of the size presented in this analysis.

The pre=post removal standard can be met in Anchorage and for residential and industrial development in Juneau. Meeting this standard comes at annualized costs, including O&M, ranging from $490 per developed acre for industrial development to $1640 per developed residential acre.

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Appendix A

MONTGOMERY WATSON

Appendix A

Daily Runoff and TSS Load from Rainfall and Snowmelt Events for Typical Year

- Anchorage
- Bethel
- Juneau

Derivation of Snowmelt Runoff and TSS Loading from North Arctic/Orbit Data

Derivation of Annual Predevelopment TSS based on Universal Soil Loss Equation

Daily Runoff and TSS Load from Rainfall and Snowmelt Events For Typical Year

- Anchorage
- Bethel
- Juneau

					Residential					Industrial			
					Area:	5 ac				Area:	10 ac		
					% imp:	38				% imp:	50		
Assumed Day of Melt	Date	Precip	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs
11	12-Jan		0.03	157		0.04	7	0.01	157		0.05	17	0.02
12	13-Jan		0.03	151		0.04	6	0.01	151		0.05	16	0.02
13	14-Jan		0.03	146		0.04	6	0.01	146		0.05	16	0.02
4	22-Feb		0.03	195		0.04	8	0.01	195		0.05	21	0.02
5	23-Feb		0.03	190		0.04	8	0.01	190		0.05	21	0.02
6	24-Feb		0.03	184		0.04	8	0.01	184		0.05	20	0.02
7	25-Feb		0.03	179		0.04	8	0.01	179		0.05	19	0.02
8	26-Feb		0.03	173		0.04	7	0.01	173		0.05	19	0.02
1	10-Mar		0.04679	212		0.06	14	0.01	212		0.07	36	0.03
2	11-Mar		0.02298	206		0.03	7	0.01	206		0.04	17	0.02
3	12-Mar		0.04679	201		0.06	13	0.01	201		0.07	34	0.03
4	13-Mar		0.03002	195		0.04	8	0.01	195		0.05	21	0.02
5	14-Mar		0.01967	190		0.02	5	0.01	190		0.03	14	0.01
6	15-Mar		0.01967	184		0.02	5	0.01	184		0.03	13	0.01
7	16-Mar		0.01967	179		0.02	5	0.01	179		0.03	13	0.01
8	17-Mar		0.01967	173		0.02	5	0.01	173		0.03	12	0.01
9	18-Mar		0.0352	168		0.04	8	0.01	168		0.06	21	0.02
10	19-Mar		0.04037	162		0.05	9	0.01	162		0.06	24	0.03
11	20-Mar		0.04058	157		0.05	9	0.01	157		0.06	23	0.03
12	21-Mar		0.0383	151		0.05	8	0.01	151		0.06	21	0.03
13	22-Mar		0.03023	146		0.04	6	0.01	146		0.05	16	0.02
14	23-Mar		0.0383	140		0.05	8	0.01	140		0.06	20	0.03
15	24-Mar		0.03727	135		0.05	7	0.01	135		0.06	18	0.03
16	25-Mar		0.02588	129		0.03	5	0.01	129		0.04	12	0.02
17	26-Mar		0.0383	124		0.05	7	0.01	124		0.06	17	0.03
18	27-Mar		0.03106	118		0.04	5	0.01	118		0.05	13	0.02
19	28-Mar		0.03002	113		0.04	5	0.01	113		0.05	12	0.02
20	29-Mar		0.02588	107		0.03	4	0.01	107		0.04	10	0.02
21	30-Mar		0.04017	102		0.05	6	0.01	102		0.06	15	0.03
22	31-Mar		0.04617	96		0.06	6	0.01	96		0.07	16	0.03
23	1-Apr		0.04617	91		0.06	6	0.01	91		0.07	15	0.03
24	2-Apr		0.06336	85		0.08	8	0.02	85		0.10	20	0.04
25	3-Apr		0.0499	80		0.06	6	0.01	80		0.08	14	0.03
26	4-Apr		0.0354	75		0.04	4	0.01	75		0.06	10	0.02
27	5-Apr		0.04679	69		0.06	5	0.01	69		0.07	12	0.03
28	6-Apr		0.05176	64		0.06	5	0.01	64		0.08	12	0.03
29	7-Apr		0.05176	58		0.06	4	0.01	58		0.08	11	0.03
30	8-Apr		0.03894	53		0.05	3	0.01	53		0.06	7	0.03
31	9-Apr		0.05073	47		0.06	3	0.01	47		0.08	9	0.03
32	10-Apr		0.06522	42		0.08	4	0.02	42		0.10	10	0.04
33	11-Apr		0.05176	36		0.06	3	0.01	36		0.08	7	0.03
34	12-Apr		0.08157	31		0.10	4	0.02	31		0.13	9	0.05
35	13-Apr		0.0793	25		0.10	3	0.02	25		0.13	7	0.05
36	14-Apr		0.08758	20		0.11	2	0.02	20		0.14	6	0.06
37	15-Apr		0.11346	14		0.14	2	0.03	14		0.18	6	0.08
	22-May	0.09			0.02		4	0.01	139	0.03		11	0.01
	24-May	0.09			0.02		4	0.01	139	0.03		11	0.01
	31-May	0.15			0.04		6	0.01	132	0.05		18	0.02
	6-Jun	0.14			0.04		6	0.01	133	0.05		17	0.02
	19-Jun	0.16			0.05		7	0.01	131	0.06		20	0.02
	20-Jun	0.26			0.08		11	0.02	124	0.09		32	0.04
	22-Jun	0.1			0.03		4	0.01	138	0.03		12	0.01
	30-Jun	0.12			0.03		5	0.01	135	0.04		15	0.02
	1-Jul	0.28			0.08		12	0.02	123	0.10		34	0.04
	9-Jul	0.18			0.05		8	0.01	129	0.06		22	0.03
	13-Jul	0.12			0.03		5	0.01	135	0.04		15	0.02
	18-Jul	0.55			0.18		23	0.04	114	0.21		67	0.09
	24-Jul	0.09			0.02		4	0.01	139	0.03		11	0.01
	25-Jul	0.12			0.03		5	0.01	135	0.04		15	0.02
	3-Aug	0.15			0.04		6	0.01	132	0.05		18	0.02
	9-Aug	0.2			0.06		8	0.01	128	0.07		24	0.03
	12-Aug	0.11			0.03		5	0.01	136	0.04		14	0.02
	13-Aug	0.3			0.09		12	0.02	122	0.11		37	0.05

					Residential					Industrial			
					Area:	5 ac				Area:	10 ac		
					% imp:	38				% imp:	50		
Assumed Day of Melt	Date	Precip	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs
	14-Aug	0.26			0.08		11	0.02	124	0.09		32	0.04
	16-Aug	0.1			0.03		4	0.01	138	0.03		12	0.01
	23-Aug	0.24			0.07		10	0.01	125	0.09		29	0.04
	4-Sep	0.16			0.05		7	0.01	131	0.06		20	0.02
	6-Sep	0.17			0.05		7	0.01	130	0.06		21	0.02
	8-Sep	0.27			0.08		11	0.02	124	0.10		33	0.04
	11-Sep	0.14			0.04		6	0.01	133	0.05		17	0.02
	14-Sep	0.16			0.05		7	0.01	131	0.06		20	0.02
	15-Sep	0.18			0.05		8	0.01	129	0.06		22	0.03
	17-Sep	0.51			0.16		21	0.03	115	0.20		62	0.08
	18-Sep	0.12			0.03		5	0.01	135	0.04		15	0.02
	19-Sep	0.64			0.21		26	0.04	112	0.25		77	0.11
	20-Sep	0.14			0.04		6	0.01	133	0.05		17	0.02
	23-Sep	0.34			0.10		14	0.02	120	0.13		41	0.05
	26-Sep	0.39			0.12		16	0.03	119	0.15		47	0.06
	27-Sep	0.47			0.15		19	0.03	116	0.18		57	0.08
	29-Sep	0.34			0.10		14	0.02	120	0.13		41	0.05
	30-Sep	0.29			0.09		12	0.02	123	0.11		35	0.04
	6-Oct	0.44			0.14		18	0.03	117	0.17		53	0.07
	8-Oct	0.12			0.03		5	0.01	135	0.04		15	0.02
	10-Oct	0.42			0.13		17	0.03	118	0.16		51	0.07
	13-Oct	0.09			0.02		4	0.01	139	0.03		11	0.01
	24-Oct	0.14			0.04		6	0.01	133	0.05		17	0.02
	25-Oct	0.11			0.03		5	0.01	136	0.04		14	0.02
26	11-Nov		0.03	75		0.04	3	0.01	75		0.05	8	0.02
27	12-Nov		0.03	69		0.04	3	0.01	69		0.05	8	0.02
28	13-Nov		0.03	64		0.04	3	0.01	64		0.05	7	0.02
29	14-Nov		0.03	58		0.04	2	0.01	58		0.05	6	0.02
30	15-Nov		0.03	53		0.04	2	0.01	53		0.05	6	0.02
31	16-Nov		0.03	47		0.04	2	0.01	47		0.05	5	0.02
32	17-Nov		0.03	42		0.04	2	0.01	42		0.05	5	0.02
33	18-Nov		0.03	36		0.04	2	0.01	36		0.05	4	0.02
18	15-Dec		0.03	118		0.04	5	0.01	118		0.05	13	0.02
19	16-Dec		0.03	113		0.04	5	0.01	113		0.05	12	0.02
20	17-Dec		0.03	107		0.04	5	0.01	107		0.05	12	0.02
	Total	9.45			2.8	2.7	699	1.2		3.4	3.5	1942	2.9
	Median Day	0.16			0.1	0.0	7.1	0.0	128	0.1	0.1	19.8	0.02
	Rain	9.45			2.4		338	0.01	130	3.0		992	0.02
	Snowmelt					2.7	361	0.01	113		3.5	950	0.02
	Maximum	0.64			0.2	0.1	26.4	0.04		0.3	0.2	77.4	0.11
	Minimum	0.09			0.0	0.0	1.5	0.0		0.0	0.0	3.9	0.0
	Winter % of Total						52%					49%	

					Commercial					Pre-development			
					Area:		10 ac			Area:		10 ac	
					% imp:		85			% imp:		2	
Assumed Day of Melt	Date	Precip	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	Runoff cfs
11	12-Jan		0.03	157	157		0.08	28	0.03	157		0.00	0.002
12	13-Jan		0.03	151	151		0.08	27	0.03	151		0.00	0.002
13	14-Jan		0.03	146	146		0.08	26	0.03	146		0.00	0.002
4	22-Feb		0.03	195	195		0.08	35	0.03	195		0.00	0.002
5	23-Feb		0.03	190	190		0.08	34	0.03	190		0.00	0.002
6	24-Feb		0.03	184	184		0.08	33	0.03	184		0.00	0.002
7	25-Feb		0.03	179	179		0.08	32	0.03	179		0.00	0.002
8	26-Feb		0.03	173	173		0.08	31	0.03	173		0.00	0.002
1	10-Mar		0.04679	212	212		0.12	60	0.05	212		0.01	0.003
2	11-Mar		0.02298	206	206		0.06	28	0.03	206		0.00	0.002
3	12-Mar		0.04679	201	201		0.12	56	0.05	201		0.01	0.003
4	13-Mar		0.03002	195	195		0.08	35	0.03	195		0.00	0.002
5	14-Mar		0.01967	190	190		0.05	22	0.02	190		0.00	0.001
6	15-Mar		0.01967	184	184		0.05	22	0.02	184		0.00	0.001
7	16-Mar		0.01967	179	179		0.05	21	0.02	179		0.00	0.001
8	17-Mar		0.01967	173	173		0.05	20	0.02	173		0.00	0.001
9	18-Mar		0.0352	168	168		0.09	35	0.04	168		0.01	0.002
10	19-Mar		0.04037	162	162		0.11	39	0.04	162		0.01	0.003
11	20-Mar		0.04058	157	157		0.11	38	0.05	157		0.01	0.003
12	21-Mar		0.0383	151	151		0.10	35	0.04	151		0.01	0.003
13	22-Mar		0.03023	146	146		0.08	26	0.03	146		0.00	0.002
14	23-Mar		0.0383	140	140		0.10	32	0.04	140		0.01	0.003
15	24-Mar		0.03727	135	135		0.10	30	0.04	135		0.01	0.003
16	25-Mar		0.02588	129	129		0.07	20	0.03	129		0.00	0.002
17	26-Mar		0.0383	124	124		0.10	29	0.04	124		0.01	0.003
18	27-Mar		0.03106	118	118		0.08	22	0.03	118		0.00	0.002
19	28-Mar		0.03002	113	113		0.08	20	0.03	113		0.00	0.002
20	29-Mar		0.02588	107	107		0.07	17	0.03	107		0.00	0.002
21	30-Mar		0.04017	102	102		0.11	25	0.04	102		0.01	0.003
22	31-Mar		0.04617	96	96		0.12	27	0.05	96		0.01	0.003
23	1-Apr		0.04617	91	91		0.12	25	0.05	91		0.01	0.003
24	2-Apr		0.06336	85	85		0.17	33	0.07	85		0.01	0.004
25	3-Apr		0.0499	80	80		0.13	24	0.06	80		0.01	0.003
26	4-Apr		0.0354	75	75		0.09	16	0.04	75		0.01	0.002
27	5-Apr		0.04679	69	69		0.12	19	0.05	69		0.01	0.003
28	6-Apr		0.05176	64	64		0.14	20	0.06	64		0.01	0.003
29	7-Apr		0.05176	58	58		0.14	18	0.06	58		0.01	0.003
30	8-Apr		0.03894	53	53		0.10	12	0.04	53		0.01	0.003
31	9-Apr		0.05073	47	47		0.13	14	0.06	47		0.01	0.003
32	10-Apr		0.06522	42	42		0.17	16	0.07	42		0.01	0.004
33	11-Apr		0.05176	36	36		0.14	11	0.06	36		0.01	0.003
34	12-Apr		0.08157	31	31		0.22	15	0.09	31		0.01	0.005
35	13-Apr		0.0793	25	25		0.21	12	0.09	25		0.01	0.005
36	14-Apr		0.08758	20	20		0.23	10	0.10	20		0.01	0.006
37	15-Apr		0.11346	14	14		0.30	10	0.13	14		0.02	0.008
	22-May	0.09			167	0.04		19	0.02	239	0.01		0.004
	24-May	0.09			167	0.04		19	0.02	239	0.01		0.004
	31-May	0.15			158	0.06		32	0.03	226	0.02		0.006
	6-Jun	0.14			159	0.06		30	0.02	227	0.01		0.006
	19-Jun	0.16			157	0.07		34	0.03	224	0.02		0.007
	20-Jun	0.26			149	0.12		55	0.05	213	0.03		0.012
	22-Jun	0.1			165	0.04		22	0.02	236	0.01		0.004
	30-Jun	0.12			162	0.05		26	0.02	231	0.01		0.005
	1-Jul	0.28			148	0.12		60	0.05	211	0.03		0.013
	9-Jul	0.18			155	0.08		39	0.03	221	0.02		0.008
	13-Jul	0.12			162	0.05		26	0.02	231	0.01		0.005
	18-Jul	0.55			137	0.26		116	0.11	196	0.06		0.027
	24-Jul	0.09			167	0.04		19	0.02	239	0.01		0.004
	25-Jul	0.12			162	0.05		26	0.02	231	0.01		0.005
	3-Aug	0.15			158	0.06		32	0.03	226	0.02		0.006
	9-Aug	0.2			153	0.09		43	0.04	219	0.02		0.009
	12-Aug	0.11			164	0.04		24	0.02	234	0.01		0.005
	13-Aug	0.3			146	0.13		64	0.06	209	0.03		0.014

					Commercial					Pre-development			
						Area:	10 ac				Area:	10 ac	
						% imp:	85				% imp:	2	
Assumed Day of Melt	Date	Precip	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	TSS concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	Runoff cfs
	14-Aug	0.26			149	0.12		55	0.05	213	0.03		0.012
	16-Aug	0.1			165	0.04		22	0.02	236	0.01		0.004
	23-Aug	0.24			150	0.11		51	0.04	214	0.03		0.011
	4-Sep	0.16			157	0.07		34	0.03	224	0.02		0.007
	6-Sep	0.17			156	0.07		36	0.03	223	0.02		0.007
	8-Sep	0.27			148	0.12		58	0.05	212	0.03		0.012
	11-Sep	0.14			159	0.06		30	0.02	227	0.01		0.006
	14-Sep	0.16			157	0.07		34	0.03	224	0.02		0.007
	15-Sep	0.18			155	0.08		39	0.03	221	0.02		0.008
	17-Sep	0.51			138	0.24		108	0.10	197	0.06		0.024
	18-Sep	0.12			162	0.05		26	0.02	231	0.01		0.005
	19-Sep	0.64			135	0.31		135	0.13	192	0.07		0.031
	20-Sep	0.14			159	0.06		30	0.02	227	0.01		0.006
	23-Sep	0.34			144	0.15		72	0.06	206	0.04		0.016
	26-Sep	0.39			142	0.18		83	0.08	203	0.04		0.018
	27-Sep	0.47			139	0.22		100	0.09	199	0.05		0.022
	29-Sep	0.34			144	0.15		72	0.06	206	0.04		0.016
	30-Sep	0.29			147	0.13		62	0.05	210	0.03		0.013
	6-Oct	0.44			140	0.21		93	0.09	201	0.05		0.021
	8-Oct	0.12			162	0.05		26	0.02	231	0.01		0.005
	10-Oct	0.42			141	0.19		89	0.08	202	0.05		0.020
	13-Oct	0.09			167	0.04		19	0.02	239	0.01		0.004
	24-Oct	0.14			159	0.06		30	0.02	227	0.01		0.006
	25-Oct	0.11			164	0.04		24	0.02	234	0.01		0.005
26	11-Nov		0.03	75	75		0.08	13	0.03	75		0.00	0.002
27	12-Nov		0.03	69	69		0.08	12	0.03	69		0.00	0.002
28	13-Nov		0.03	64	64		0.08	11	0.03	64		0.00	0.002
29	14-Nov		0.03	58	58		0.08	10	0.03	58		0.00	0.002
30	15-Nov		0.03	53	53		0.08	9	0.03	53		0.00	0.002
31	16-Nov		0.03	47	47		0.08	9	0.03	47		0.00	0.002
32	17-Nov		0.03	42	42		0.08	8	0.03	42		0.00	0.002
33	18-Nov		0.03	36	36		0.08	7	0.03	36		0.00	0.002
18	15-Dec		0.03	118	118		0.08	21	0.03	118		0.00	0.002
19	16-Dec		0.03	113	113		0.08	20	0.03	113		0.00	0.002
20	17-Dec		0.03	107	107		0.08	19	0.03	107		0.00	0.002
Total		9.45				4.2	5.8	3322	4.2		0.87	0.35	0.01
Median Day		0.16			148	0.1	0.1	33.9	0.0	187			
Rain		9.45			156	3.6		1734	0.03	223	0.87		0.01
Snowmelt					113		5.8	1588	0.03	113		0.35	0.00
Maximum		0.64				0.3	0.3	135.3	0.13				
Minimum		0.09				0.0	0.1	6.5	0.0				
Winter % of Total								48%					

JUNEAU

	Residential		Industrial	
Area:	5 ac		20 ac	
% imp:	40	S:	50	S:
CN AMC II:	83	2.0	86	1.6
CN AMC III:	93	0.8	94	0.6

Day of Melt	Date	Precip	Snowmelt for imp=30	Snowmelt TSS conc (mg/l)	Residential Rainfall Runoff in	Residential Snowmelt Runoff	Residential TSS lbs	Residential Runoff cfs	Residential Concentration mg/l	Industrial Rainfall Runoff in	Industrial Snowmelt Runoff	Industrial TSS lbs	Industrial Runoff cfs	Industrial Concentration mg/l
	1	2	3	4	6	7	8	9	10	11	12	13	14	15
	1/5/87	0.13		0	n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	1/7/87	0.23			0.01		1	0.00	162	0.01		12	0.01	181
	1/8/87	0.5			0.11		16	0.02	124	0.14		90	0.12	144
	1/9/87	0.52			0.12		17	0.03	123	0.15		97	0.13	143
	1/15/87	0.15			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	1/16/87	0.98			0.43		53	0.09	108	0.49		281	0.41	127
	1/17/87	0.46			0.09		13	0.02	127	0.11		76	0.10	147
22	1/18/87		0.03	96.44	n/a	0.04	4	0.01	85	n/a	0.05	0	0.01	0
23	1/19/87	0.62	0.03	90.96	0.18	0.04	28	0.05	113	0.21	0.05	154	0.22	129
	2/2/87	0.15			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	2/4/87	0.13			n/a		n/a	n/a	n/a	0.00		0	0.00	380
	2/5/87	0.22			0.01		1	0.00	166	0.01		10	0.01	185
	2/6/87	0.16			0.00		0	0.00	246	0.00		2	0.00	226
	2/8/87	0.53			0.13		18	0.03	122	0.16		101	0.13	142
	2/9/87	0.4			0.06		9	0.01	131	0.08		56	0.07	152
	2/16/87	0.16			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	2/19/87	0.19			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	2/20/87	0.35			0.04		6	0.01	137	0.06		41	0.05	157
	2/21/87	0.17			0.00		0	0.00	213	0.00		3	0.00	214
	2/25/87	0.29			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	3/16/87	0.15			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	3/24/87	0.16			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	3/28/87	0.99			0.13		18	0.03	122	0.19		122	0.16	139
	3/29/87	0.27			0.02		3	0.00	150	0.03		20	0.02	170
	3/30/87	0.1			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/3/87	0.18			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/9/87	0.18			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/14/87	0.29			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/16/87	0.35			0.04		6	0.01	137	0.06		41	0.05	157
	4/19/87	0.2			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/20/87	0.11			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/27/87	0.12			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	4/28/87	0.11			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	5/1/87	0.16			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	5/2/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	5/3/87	0.23			0.01		1	0.00	162	0.01		12	0.01	181
	5/4/87	0.15			n/a		n/a	n/a	n/a	0.00		1	0.00	243
	5/6/87	0.45			0.09		12	0.02	127	0.11		73	0.09	148
	5/8/87	0.13			n/a		n/a	n/a	n/a	0.00		0	0.00	380
	5/23/87	0.5			0.00		1	0.00	174	0.02		14	0.01	178
	5/26/87	0.28			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	5/27/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	6/2/87	0.34			n/a		n/a	n/a	n/a	0.00		0	0.00	290
	6/5/87	0.5			0.00		1	0.00	174	0.02		14	0.01	178
	6/8/87	0.9			0.09		14	0.02	126	0.15		97	0.13	143
	6/11/87	0.16			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	6/12/87	0.15			n/a		n/a	n/a	n/a	0.00		1	0.00	243
	6/13/87	0.4			0.06		9	0.01	131	0.08		56	0.07	152
	6/16/87	0.27			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	6/17/87	0.96			0.42		52	0.09	109	0.47		273	0.40	128
	6/18/87	0.31			0.03		5	0.01	142	0.04		30	0.03	163
	6/19/87	0.26			0.01		2	0.00	153	0.02		18	0.02	173
	6/21/87	0.75			0.27		34	0.06	114	0.31		186	0.26	133
	6/22/87	0.15			n/a		n/a	n/a	n/a	0.00		1	0.00	243
	6/24/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	6/25/87	0.54			0.13		18	0.03	122	0.16		104	0.14	142
	7/11/87	0.36			n/a		n/a	n/a	n/a	0.00		1	0.00	244
	7/12/87	0.13			n/a		n/a	n/a	n/a	0.00		0	0.00	380
	7/13/87	0.26			0.01		2	0.00	153	0.02		18	0.02	173
	7/14/87	0.61			0.17		23	0.04	119	0.21		130	0.17	138
	7/26/87	0.14			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	7/27/87	0.26			0.01		2	0.00	153	0.02		18	0.02	173
	7/28/87	0.2			0.00		1	0.00	178	0.01		6	0.01	193
	7/29/87	0.52			0.12		17	0.03	123	0.15		97	0.13	143
	8/6/87	0.15			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	8/14/87	0.15			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	8/15/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	8/16/87	0.17			0.00		0	0.00	213	0.00		3	0.00	214
	8/17/87	0.29			0.02		4	0.00	146	0.03		25	0.03	166
	8/21/87	0.24			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	8/26/87	1.11			0.18		24	0.04	118	0.26		157	0.21	136
	8/30/87	1.82			0.58		69	0.12	105	0.72		397	0.60	122
	8/31/87	0.41			0.07		10	0.01	131	0.09		59	0.07	151
	9/2/87	0.21			0.00		1	0.00	171	0.01		8	0.01	189
	9/3/87	0.21			0.00		1	0.00	171	0.01		8	0.01	189
	9/4/87	0.74			0.26		33	0.05	114	0.30		182	0.25	133
	9/7/87	0.5			0.00		1	0.00	174	0.02		14	0.01	178
	9/9/87	0.34			0.04		6	0.01	138	0.05		38	0.04	159
	9/10/87	1.22			0.63		74	0.13	104	0.69		384	0.58	123
	9/11/87	0.44			0.08		12	0.02	128	0.10		69	0.09	148

	Residential			Industrial		
Area:	5 ac			Area:	20 ac	
% imp:	40	S:		% imp:	50	S:
CN AMC II:	83	2.0		CN AMC II:	86	1.6
CN AMC III:	93	0.8		CN AMC III:	94	0.6

					Residential					Industrial				
	1	2	3	4	6	7	8	9	10	11	12	13	14	15
Day of Melt	Date	Precip	Snowmelt for imp=30	Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	Concentration mg/l
	9/12/87	0.17			0.00		0	0.00	213	0.00		3	0.00	214
	9/14/87	0.12			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	9/15/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	9/16/87	0.16			0.00		0	0.00	246	0.00		2	0.00	226
	9/17/87	0.43			0.08		11	0.02	129	0.10		66	0.08	149
	9/18/87	0.13			n/a		n/a	n/a	n/a	0.00		0	0.00	380
	9/19/87	0.45			0.09		12	0.02	127	0.11		73	0.09	148
	9/21/87	0.11			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	9/27/87	0.3			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	9/28/87	0.69			0.23		30	0.05	116	0.26		162	0.22	135
	9/29/87	0.65			0.20		26	0.04	117	0.24		146	0.20	137
	9/30/87	0.63			0.19		25	0.04	118	0.22		138	0.19	138
	10/1/87	0.9			0.37		47	0.08	110	0.42		247	0.36	129
	10/2/87	0.46			0.09		13	0.02	127	0.11		76	0.10	147
	10/3/87	0.35			0.04		6	0.01	137	0.06		41	0.05	157
	10/4/87	0.69			0.23		30	0.05	116	0.26		162	0.22	135
	10/5/87	0.53			0.13		18	0.03	122	0.16		101	0.13	142
	10/6/87	0.19			0.00		0	0.00	186	0.01		5	0.00	199
	10/10/87	1.06			0.16		21	0.03	120	0.23		142	0.19	137
	10/11/87	0.67			0.21		28	0.04	116	0.25		154	0.21	136
	10/12/87	0.18			0.00		0	0.00	197	0.00		4	0.00	206
	10/13/87	0.35			0.04		6	0.01	137	0.06		41	0.05	157
	10/14/87	0.31			0.03		5	0.01	142	0.04		30	0.03	163
	10/15/87	0.2			0.00		1	0.00	178	0.01		6	0.01	193
	10/17/87	0.14			n/a		n/a	n/a	n/a	0.00		0	0.00	273
	10/18/87	0.29			0.02		4	0.00	146	0.03		25	0.03	166
	10/19/87	0.56			0.14		20	0.03	121	0.17		112	0.15	141
	10/22/87	0.26			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	10/23/87	0.57			0.15		20	0.03	120	0.18		115	0.15	140
	10/24/87	0.73			0.25		33	0.05	114	0.29		177	0.25	134
	10/26/87	0.56			0.14		20	0.03	121	0.17		112	0.15	141
	10/27/87	0.37			0.05		8	0.01	134	0.07		47	0.06	155
	10/28/87	0.31			0.03		5	0.01	142	0.04		30	0.03	163
	10/30/87	0.1			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	10/31/87	0.19			0.00		0	0.00	186	0.01		5	0.00	199
	11/1/87	0.46			0.09		13	0.02	127	0.11		76	0.10	147
	11/2/87	0.57			0.15		20	0.03	120	0.18		115	0.15	140
	11/3/87	0.17			0.00		0	0.00	213	0.00		3	0.00	214
	11/5/87	0.53			0.13		18	0.03	122	0.16		101	0.13	142
	11/6/87	0.23			0.01		1	0.00	162	0.01		12	0.01	181
	11/8/87	0.38			0.05		8	0.01	133	0.07		50	0.06	154
	11/9/87	0.5			0.11		16	0.02	124	0.14		90	0.12	144
	11/10/87	0.24			0.01		2	0.00	159	0.02		14	0.01	178
	11/11/87	0.11			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	11/12/87	0.11			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	11/14/87	0.25			0.01		2	0.00	155	0.02		16	0.02	175
	11/15/87				n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	11/17/87				n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
30	11/18/87		0.03	52.6	n/a	0.04	2	0.01	46	n/a	0.05	0	0.01	0
31	11/19/87	0.11	0.03	47.12	n/a	0.04	2	0.01	42	n/a	0.05	0	0.01	0
32	11/20/87		0.03	41.64	n/a	0.04	2	0.01	37	n/a	0.05	0	0.01	0
	11/24/87	0.47			0.00		0	0.00	188	0.01		10	0.01	184
	11/25/87	0.16			0.00		0	0.00	246	0.00		2	0.00	226
	11/26/87	0.15			n/a		n/a	n/a	n/a	0.00		1	0.00	243
	11/27/87	0.52			0.12		17	0.03	123	0.15		97	0.13	143
	11/28/87	0.62			0.18		24	0.04	118	0.21		134	0.18	138
	11/29/87	0.5			0.11		16	0.02	124	0.14		90	0.12	144
	12/2/87	0.24			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	12/3/87	0.12			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	12/4/87	0.19			0.00		0	0.00	186	0.01		5	0.00	199
	12/10/87	0.36			n/a		n/a	n/a	n/a	0.00		1	0.00	244
	12/12/87	0.63			0.19		25	0.04	118	0.22		138	0.19	138
	12/13/87	0.26			0.01		2	0.00	153	0.02		18	0.02	173
	12/16/87				n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
26	12/17/87	0.44	0.03	74.52	0.08	0.04	15	0.03	111	0.10	0.05	85	0.13	125
27	12/19/87	0.24	0.03	69.04	0.01	0.04	5	0.01	87	0.02	0.05	29	0.05	97
28	12/20/87	0.27	0.03	63.56	0.02	0.04	6	0.01	89	0.03	0.05	34	0.06	101
	12/23/87	0.2			n/a		n/a	n/a	n/a	n/a		n/a	n/a	n/a
	12/24/87	1.13			0.55		66	0.12	106	0.61		345	0.51	124
	12/25/87	0.45			0.09		12	0.02	127	0.11		73	0.09	148
	Total	52.74			9.46	0.31	1285			11.63	0.38	7351		
	Median Day	0.27			0.06	0.04	8.69	0.01	127	0.05	0.05	29.96	0.04	157
	Rain (Feb-C	38.54			6.59		879	0.01	133	8.17		5106	0.03	163
	Maximum	1.82			0.63	0.04	74	0.13	246.04	0.72	0.05	397	0.60	379.86
	Minimum	0.1			0.00	0.04	0	0.00	36.70	0.00	0.05	0	0.00	0.01

					Commercial					Pre-development		
					Area:	15 ac				Area:	20 ac	
					% imp:	85		S:		% imp:	2	S:
					CN AMC II:	94		0.6		CN AMC II:	70	4.3
					CN AMC III:	98.0		0.2		CN AMC III:	85	1.8
	1	2	3	4	16	17	18	19	20	21	22	23
Day of Melt	Date	Precip	Snowmelt for imp=30	Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	Runoff cfs
	1/5/87	0.13		0	0.00		0	0.00	552	n/a		0.00
	1/7/87	0.23			0.09		68	0.06	218	n/a		0.00
	1/8/87	0.5			0.32		209	0.20	193	0.01		0.01
	1/9/87	0.52			0.34		219	0.21	192	0.01		0.01
	1/15/87	0.15			0.00		1	0.00	353	n/a		0.00
	1/16/87	0.98			0.77		463	0.49	176	0.16		0.14
	1/17/87	0.46			0.28		187	0.18	195	0.01		0.01
22	1/18/87		0.03	96.44	n/a	0.08	0	0.02	0	n/a	0.00	0.00
23	1/19/87	0.62	0.03	90.96	0.43	0.08	297	0.32	172	0.04	0.00	0.03
	2/2/87	0.15			0.00		1	0.00	353	n/a		0.00
	2/4/87	0.13			0.03		23	0.02	247	n/a		0.00
	2/5/87	0.22			0.08		63	0.05	220	n/a		0.00
	2/6/87	0.16			0.04		35	0.03	235	n/a		0.00
	2/8/87	0.53			0.35		225	0.22	191	0.02		0.01
	2/9/87	0.4			0.23		155	0.14	199	0.00		0.00
	2/16/87	0.16			0.00		2	0.00	328	n/a		0.00
	2/19/87	0.19			0.01		5	0.00	289	n/a		0.00
	2/20/87	0.35			0.19		129	0.12	203	n/a		0.00
	2/21/87	0.17			0.05		40	0.03	232	n/a		0.00
	2/25/87	0.29			0.03		27	0.02	242	n/a		0.00
	3/16/87	0.15			0.00		1	0.00	353	n/a		0.00
	3/24/87	0.16			0.00		2	0.00	328	n/a		0.00
	3/28/87	0.99			0.50		311	0.31	184	0.00		0.00
	3/29/87	0.27			0.12		88	0.08	212	n/a		0.00
	3/30/87	0.1			0.01		12	0.01	265	n/a		0.00
	4/3/87	0.18			0.00		4	0.00	299	n/a		0.00
	4/9/87	0.18			0.00		4	0.00	299	n/a		0.00
	4/14/87	0.29			0.03		27	0.02	242	n/a		0.00
	4/16/87	0.35			0.19		129	0.12	203	n/a		0.00
	4/19/87	0.2			0.01		7	0.00	281	n/a		0.00
	4/20/87	0.11			0.02		15	0.01	258	n/a		0.00
	4/27/87	0.12			n/a		n/a	n/a	n/a	n/a		0.00
	4/28/87	0.11			0.02		15	0.01	258	n/a		0.00
	5/1/87	0.16			0.00		2	0.00	328	n/a		0.00
	5/2/87	0.14			0.03		27	0.02	242	n/a		0.00
	5/3/87	0.23			0.09		68	0.06	218	n/a		0.00
	5/4/87	0.15			0.04		31	0.02	238	n/a		0.00
	5/6/87	0.45			0.27		182	0.17	196	0.01		0.00
	5/8/87	0.13			0.03		23	0.02	247	n/a		0.00
	5/23/87	0.5			0.14		98	0.09	210	n/a		0.00
	5/26/87	0.28			0.03		24	0.02	245	n/a		0.00
	5/27/87	0.14			0.03		27	0.02	242	n/a		0.00
	6/2/87	0.34			0.05		42	0.03	231	n/a		0.00
	6/5/87	0.5			0.14		98	0.09	210	n/a		0.00
	6/8/87	0.9			0.42		270	0.27	187	0.00		0.00
	6/11/87	0.16			0.00		2	0.00	328	n/a		0.00
	6/12/87	0.15			0.04		31	0.02	238	n/a		0.00
	6/13/87	0.4			0.23		155	0.14	199	0.00		0.00
	6/16/87	0.27			0.03		22	0.02	248	n/a		0.00
	6/17/87	0.96			0.75		453	0.47	177	0.16		0.13
	6/18/87	0.31			0.15		108	0.10	207	n/a		0.00
	6/19/87	0.26			0.11		83	0.07	214	n/a		0.00
	6/21/87	0.75			0.55		342	0.35	182	0.07		0.06
	6/22/87	0.15			0.04		31	0.02	238	n/a		0.00
	6/24/87	0.14			0.03		27	0.02	242	n/a		0.00
	6/25/87	0.54			0.35		230	0.22	191	0.02		0.02
	7/11/87	0.36			0.06		48	0.04	227	n/a		0.00
	7/12/87	0.13			0.03		23	0.02	247	n/a		0.00
	7/13/87	0.26			0.11		83	0.07	214	n/a		0.00
	7/14/87	0.61			0.42		267	0.26	187	0.03		0.03
	7/26/87	0.14			0.00		0	0.00	397	n/a		0.00
	7/27/87	0.26			0.11		83	0.07	214	n/a		0.00
	7/28/87	0.2			0.07		53	0.04	224	n/a		0.00
	7/29/87	0.52			0.34		219	0.21	192	0.01		0.01
	8/6/87	0.15			0.00		1	0.00	353	n/a		0.00
	8/14/87	0.15			0.00		1	0.00	353	n/a		0.00
	8/15/87	0.14			0.03		27	0.02	242	n/a		0.00
	8/16/87	0.17			0.05		40	0.03	232	n/a		0.00
	8/17/87	0.29			0.14		98	0.09	210	n/a		0.00
	8/21/87	0.24			0.02		15	0.01	259	n/a		0.00
	8/26/87	1.11			0.60		367	0.38	181	0.01		0.01
	8/30/87	1.82			1.23		704	0.77	168	0.18		0.15
	8/31/87	0.41			0.24		161	0.15	198	0.00		0.00
	9/2/87	0.21			0.08		58	0.05	222	n/a		0.00
	9/3/87	0.21			0.08		58	0.05	222	n/a		0.00
	9/4/87	0.74			0.54		337	0.34	183	0.07		0.06
	9/7/87	0.5			0.14		98	0.09	210	n/a		0.00
	9/9/87	0.34			0.18		124	0.11	204	n/a		0.00
	9/10/87	1.22			1.01		588	0.63	172	0.29		0.24
	9/11/87	0.44			0.26		177	0.17	196	0.00		0.00

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					Commercial					Pre-development		
					Area:	15 ac				Area:	20 ac	
					% imp:	85	S:			% imp:	2	S:
					CN AMC II:	94	0.6			CN AMC II:	70	4.3
					CN AMC III:	98.0	0.2			CN AMC III:	85	1.8
	1	2	3	4	16	17	18	19	20	21	22	23
Day of Melt	Date	Precip	Snowmelt for imp=30	Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff	TSS lbs	Runoff cfs	Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff	Runoff cfs
	9/12/87	0.17			0.05		40	0.03	232	n/a		0.00
	9/14/87	0.12			0.02		19	0.01	252	n/a		0.00
	9/15/87	0.14			0.03		27	0.02	242	n/a		0.00
	9/16/87	0.16			0.04		35	0.03	235	n/a		0.00
	9/17/87	0.43			0.26		171	0.16	197	0.00		0.00
	9/18/87	0.13			0.03		23	0.02	247	n/a		0.00
	9/19/87	0.45			0.27		182	0.17	196	0.01		0.00
	9/21/87	0.11			0.02		15	0.01	258	n/a		0.00
	9/27/87	0.3			0.04		30	0.02	239	n/a		0.00
	9/28/87	0.69			0.49		310	0.31	184	0.05		0.05
	9/29/87	0.65			0.46		289	0.29	186	0.04		0.04
	9/30/87	0.63			0.44		278	0.28	187	0.04		0.03
	10/1/87	0.9			0.69		421	0.44	178	0.13		0.11
	10/2/87	0.46			0.28		187	0.18	195	0.01		0.01
	10/3/87	0.35			0.19		129	0.12	203	n/a		0.00
	10/4/87	0.69			0.49		310	0.31	184	0.05		0.05
	10/5/87	0.53			0.35		225	0.22	191	0.02		0.01
	10/6/87	0.19			0.06		49	0.04	227	n/a		0.00
	10/10/87	1.06			0.55		343	0.35	182	0.01		0.01
	10/11/87	0.67			0.48		299	0.30	185	0.05		0.04
	10/12/87	0.18			0.06		44	0.04	229	n/a		0.00
	10/13/87	0.35			0.19		129	0.12	203	n/a		0.00
	10/14/87	0.31			0.15		108	0.10	207	n/a		0.00
	10/15/87	0.2			0.07		53	0.04	224	n/a		0.00
	10/17/87	0.14			0.03		27	0.02	242	n/a		0.00
	10/18/87	0.29			0.14		98	0.09	210	n/a		0.00
	10/19/87	0.56			0.37		241	0.23	190	0.02		0.02
	10/22/87	0.26			0.02		19	0.01	251	n/a		0.00
	10/23/87	0.57			0.38		246	0.24	189	0.02		0.02
	10/24/87	0.73			0.53		331	0.34	183	0.07		0.06
	10/26/87	0.56			0.37		241	0.23	190	0.02		0.02
	10/27/87	0.37			0.20		139	0.13	202	0.00		0.00
	10/28/87	0.31			0.15		108	0.10	207	n/a		0.00
	10/30/87	0.1			0.01		12	0.01	265	n/a		0.00
	10/31/87	0.19			0.06		49	0.04	227	n/a		0.00
	11/1/87	0.46			0.28		187	0.18	195	0.01		0.01
	11/2/87	0.57			0.38		246	0.24	189	0.02		0.02
	11/3/87	0.17			0.05		40	0.03	232	n/a		0.00
	11/5/87	0.53			0.35		225	0.22	191	0.02		0.01
	11/6/87	0.23			0.09		68	0.06	218	n/a		0.00
	11/8/87	0.38			0.21		145	0.13	201	0.00		0.00
	11/9/87	0.5			0.32		209	0.20	193	0.01		0.01
	11/10/87	0.24			0.10		73	0.06	217	n/a		0.00
	11/11/87	0.11			0.02		15	0.01	258	n/a		0.00
	11/12/87	0.11			0.02		15	0.01	258	n/a		0.00
	11/14/87	0.25			0.11		78	0.07	215	n/a		0.00
	11/15/87				n/a		n/a	n/a	n/a	n/a		0.00
	11/17/87				n/a		n/a	n/a	n/a	n/a		0.00
30	11/18/87		0.03	52.6	n/a	0.08	0	0.02	0	n/a	0.00	0.00
31	11/19/87	0.11	0.03	47.12	0.02	0.08	28	0.06	85	n/a	0.00	0.00
32	11/20/87		0.03	41.64	n/a	0.08	0	0.02	0	n/a	0.00	0.00
	11/24/87	0.47			0.12		86	0.08	213	n/a		0.00
	11/25/87	0.16			0.04		35	0.03	235	n/a		0.00
	11/26/87	0.15			0.04		31	0.02	238	n/a		0.00
	11/27/87	0.52			0.34		219	0.21	192	0.01		0.01
	11/28/87	0.62			0.43		273	0.27	187	0.04		0.03
	11/29/87	0.5			0.32		209	0.20	193	0.01		0.01
	12/2/87	0.24			0.02		15	0.01	259	n/a		0.00
	12/3/87	0.12			0.02		19	0.01	252	n/a		0.00
	12/4/87	0.19			0.06		49	0.04	227	n/a		0.00
	12/10/87	0.36			0.06		48	0.04	227	n/a		0.00
	12/12/87	0.63			0.44		278	0.28	187	0.04		0.03
	12/13/87	0.26			0.11		83	0.07	214	n/a		0.00
	12/16/87				n/a		n/a	n/a	n/a	n/a		0.00
26	12/17/87	0.44	0.03	74.52	0.26	0.08	197	0.22	168	0.00	0.00	0.01
27	12/19/87	0.24	0.03	69.04	0.10	0.08	91	0.11	151	n/a	0.00	0.00
28	12/20/87	0.27	0.03	63.56	0.12	0.08	105	0.13	153	n/a	0.00	0.00
	12/23/87	0.2			0.01		7	0.00	281	n/a		0.00
	12/24/87	1.13			0.92		541	0.58	173	0.24		0.20
	12/25/87	0.45			0.27		182	0.17	196	0.01		0.00
	Total	52.74			27.02	0.64	17782			2.05	0.04	
	Median Day	0.27			0.10	0.08	70.12	0.06	214	0.23 0.02	0.00	0.00
	Rain (Feb-C	38.54			19.18		12544	0.05	222	1.41		0.00
	Maximum	1.82			1.23	0.08	704	0.77	552.07	0.29	0.00	0.24
	Minimum	0.1			0.00	0.08	0	0.00	0.01	0.00	0.00	0.00

n/a indicates no runoff generated from storm event

Residential

					Area:	5 ac				Area:	1
					% imp:	25	S:			% imp:	40
			TR 55 Factors:		CN-AMC II	85	1.8			CN-AMC II	87
					CN-AMC III	94	0.6			CN-AMC III	95
Assumed Day of melt	Date	Rain (in)	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff in	TSS lbs	Runoff cfs	TSS Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff in
8	19-Jan		0.03	87		0.03	3	0.005	87		0.04
9	20-Jan		0.03	84		0.03	2	0.005	84		0.04
10	21-Jan		0.03	81		0.03	2	0.005	81		0.04
11	22-Jan		0.03	78		0.03	2	0.005	78		0.04
12	23-Jan		0.03	76		0.03	2	0.005	76		0.04
13	24-Jan		0.03	73		0.03	2	0.005	73		0.04
14	25-Jan		0.03	70		0.03	2	0.005	70		0.04
15	26-Jan		0.03	67		0.03	2	0.005	67		0.04
4	27-Feb		0.03	98		0.03	3	0.005	98		0.04
5	28-Feb		0.03	95		0.03	3	0.005	95		0.04
1	6-Mar		0.03	106		0.03	3	0.005	106		0.04
1	21-Mar		0.047	106		0.04	5	0.008	106		0.06
2	23-Mar		0.023	103		0.02	2	0.004	103		0.03
3	24-Mar		0.047	100		0.04	5	0.008	100		0.06
4	25-Mar		0.030	98		0.03	3	0.005	98		0.04
5	26-Mar		0.020	95		0.02	2	0.004	95		0.03
6	27-Mar		0.020	92		0.02	2	0.004	92		0.03
7	28-Mar		0.020	89		0.02	2	0.004	89		0.03
8	29-Mar		0.020	87		0.02	2	0.004	87		0.03
9	30-Mar		0.035	84		0.03	3	0.006	84		0.05
10	31-Mar		0.040	81		0.03	3	0.007	81		0.05
11	1-Apr		0.041	78		0.03	3	0.007	78		0.05
12	2-Apr		0.038	76		0.03	3	0.007	76		0.05
13	3-Apr		0.030	73		0.03	2	0.005	73		0.04
14	4-Apr		0.038	70		0.03	3	0.007	70		0.05
15	5-Apr		0.037	67		0.03	2	0.007	67		0.05
16	6-Apr		0.026	65		0.02	2	0.005	65		0.03
17	7-Apr		0.038	62		0.03	2	0.007	62		0.05
18	8-Apr		0.031	59		0.03	2	0.006	59		0.04
19	9-Apr		0.030	56		0.03	2	0.005	56		0.04
20	10-Apr		0.026	54		0.02	1	0.005	54		0.03
21	11-Apr		0.040	51		0.03	2	0.007	51		0.05
22	12-Apr		0.046	48		0.04	2	0.008	48		0.06
23	13-Apr		0.046	45		0.04	2	0.008	45		0.06
24	14-Apr		0.063	43		0.05	3	0.011	43		0.08
25	15-Apr		0.050	40		0.04	2	0.009	40		0.06
26	16-Apr		0.035	37		0.03	1	0.006	37		0.05
27	17-Apr		0.047	35		0.04	2	0.008	35		0.06
28	18-Apr		0.052	32		0.04	2	0.009	32		0.07
29	19-Apr		0.052	29		0.04	1	0.009	29		0.07
	27-May	0.17			0.00		0	0.000	n/a	0.00	
	28-May	0.29			0.03		4	0.007	100	0.05	
	6-Jun	0.22			0.00		0	0.000	n/a	0.00	
	15-Jun	0.22			0.00		0	0.000	n/a	0.00	
	16-Jun	0.27			0.03		3	0.005	103	0.04	
	23-Jun	0.12			0.00		0	0.000	n/a	0.00	
	26-Jun	0.12			0.00		0	0.000	n/a	0.00	
	15-Jul	0.31			0.00		0	0.000	n/a	0.00	
	17-Jul	0.23			0.01		2	0.003	109	0.02	
	24-Jul	0.31			0.00		0	0.000	n/a	0.00	
	28-Jul	0.12			0.00		0	0.000	n/a	0.00	
	1-Aug	0.2			0.00		0	0.000	n/a	0.00	

Residential

	Area:	5 ac		Area:	1
	% imp:	25	S:	% imp:	40
TR 55 Factors:	CN-AMC II	85	1.8	CN-AMC II	87
	CN-AMC III	94	0.6	CN-AMC III	95

Assumed Day of melt	Date	Rain (in)	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	Rainfall Runoff in	Snowmelt Runoff in	TSS lbs	Runoff cfs	TSS Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff in
	8-Aug	0.11			0.00		0	0.000	n/a	0.00	
	13-Aug	0.15			0.00		0	0.000	n/a	0.00	
	15-Aug	0.52			0.15		15	0.031	86	0.18	
	17-Aug	0.24			0.02		2	0.004	107	0.03	
	24-Aug	0.54			0.02		2	0.004	107	0.03	
	7-Sep	0.11			0.00		0	0.000	n/a	0.00	
	8-Sep	0.15			0.00		0	0.000	146	0.00	
	17-Sep	0.26			0.00		0	0.000	n/a	0.00	
	18-Sep	0.33			0.05		5	0.010	96	0.07	
	19-Sep	0.14			0.00		0	0.000	164	0.00	
	25-Sep	0.17			0.00		0	0.000	n/a	0.00	
	30-Sep	0.13			0.00		0	0.000	n/a	0.00	
	1-Oct	0.16			0.00		0	0.000	136	0.01	
	2-Oct	0.31			0.04		5	0.009	98	0.06	
	3-Oct	0.19			0.01		1	0.001	120	0.01	
	28-Oct	0.18			0.00		0	0.000	n/a	0.00	
	29-Oct	0.1			0.00		0	0.000	n/a	0.00	
	31-Oct	0.3			0.04		4	0.008	99	0.05	
24	27-Nov		0.03	43		0.03	1	0.005	43		0.04
25	28-Nov		0.03	40		0.03	1	0.005	40		0.04
22	13-Dec		0.03	48		0.03	1	0.005	48		0.04
23	14-Dec		0.03	45		0.03	1	0.005	45		0.04
	Total	6.67					140				
	Median Day	0.20			0.00	0.03	2	0.005	81	0.00	0.04
	Rain	6.67			0.39		42	0.000	107	0.55	
	Snowmelt					1.3	97	0.01	72		2.0
	Maximum Summer Day				0.15	0.05	14.61	0.031	164	0.18	0.08
	Minimum Overall				0.00	0.02	0.00	0.00	29	0.00	0.03
	TSS - Winter % of Total						70%				

n/a indicates no runoff from storm event

	Commercial			Pre-Development		
	ac		Area:	5	ac	
		S:	% imp:	2		S:
TR 55 Factors:		1.5	CN-AMC II	73		3.7
		0.5	CN-AMC III	87		1.5

Assumed Day of melt	Date	Rain (in)	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	TSS lbs	Runoff cfs	TSS Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff in	Runoff cfs
8	19-Jan		0.03	87		0.002	0		0.00	0.001
9	20-Jan		0.03	84	1	0.002	84		0.00	0.001
10	21-Jan		0.03	81	1	0.002	81		0.00	0.001
11	22-Jan		0.03	78	1	0.002	78		0.00	0.001
12	23-Jan		0.03	76	1	0.002	76		0.00	0.001
13	24-Jan		0.03	73	1	0.002	73		0.00	0.001
14	25-Jan		0.03	70	1	0.002	70		0.00	0.001
15	26-Jan		0.03	67	1	0.002	67		0.00	0.001
4	27-Feb		0.03	98	1	0.002	98		0.00	0.001
5	28-Feb		0.03	95	1	0.002	95		0.00	0.001
1	6-Mar		0.03	106	1	0.002	106		0.00	0.001
1	21-Mar		0.047	106	1	0.003	106		0.01	0.002
2	23-Mar		0.023	103	1	0.001	103		0.00	0.001
3	24-Mar		0.047	100	1	0.003	100		0.01	0.002
4	25-Mar		0.030	98	1	0.002	98		0.00	0.001
5	26-Mar		0.020	95	1	0.001	95		0.00	0.001
6	27-Mar		0.020	92	1	0.001	92		0.00	0.001
7	28-Mar		0.020	89	1	0.001	89		0.00	0.001
8	29-Mar		0.020	87	1	0.001	87		0.00	0.001
9	30-Mar		0.035	84	1	0.002	84		0.01	0.001
10	31-Mar		0.040	81	1	0.002	81		0.01	0.001
11	1-Apr		0.041	78	1	0.002	78		0.01	0.001
12	2-Apr		0.038	76	1	0.002	76		0.01	0.001
13	3-Apr		0.030	73	1	0.002	73		0.00	0.001
14	4-Apr		0.038	70	1	0.002	70		0.01	0.001
15	5-Apr		0.037	67	1	0.002	67		0.01	0.001
16	6-Apr		0.026	65	0	0.001	65		0.00	0.001
17	7-Apr		0.038	62	1	0.002	62		0.01	0.001
18	8-Apr		0.031	59	1	0.002	59		0.00	0.001
19	9-Apr		0.030	56	0	0.002	56		0.00	0.001
20	10-Apr		0.026	54	0	0.001	54		0.00	0.001
21	11-Apr		0.040	51	1	0.002	51		0.01	0.001
22	12-Apr		0.046	48	1	0.003	48		0.01	0.002
23	13-Apr		0.046	45	1	0.003	45		0.01	0.002
24	14-Apr		0.063	43	1	0.003	43		0.01	0.002
25	15-Apr		0.050	40	1	0.003	40		0.01	0.002
26	16-Apr		0.035	37	0	0.002	37		0.01	0.001
27	17-Apr		0.047	35	0	0.003	35		0.01	0.002
28	18-Apr		0.052	32	0	0.003	32		0.01	0.002
29	19-Apr		0.052	29	0	0.003	29		0.01	0.002
	27-May	0.17			0	0.000	n/a	0.00		0.000
	28-May	0.29			1	0.002	133	0.00		0.000
	6-Jun	0.22			0	0.000	n/a	0.00		0.000
	15-Jun	0.22			0	0.000	n/a	0.00		0.000
	16-Jun	0.27			1	0.002	135	0.00		0.000
	23-Jun	0.12			0	0.000	n/a	0.00		0.000
	26-Jun	0.12			0	0.000	n/a	0.00		0.000
	15-Jul	0.31			0	0.000	251	0.00		0.000
	17-Jul	0.23			1	0.001	142	0.00		0.000
	24-Jul	0.31			0	0.000	251	0.00		0.000
	28-Jul	0.12			0	0.000	n/a	0.00		0.000
	1-Aug	0.2			0	0.000	n/a	0.00		0.000

					Commercial			Pre-Development		
					ac			Area:	5 ac	
					S:			% imp:	2	S:
			TR 55 Factors:		1.5			CN-AMC II	73	3.7
					0.5			CN-AMC III	87	1.5

Assumed Day of melt	Date	Rain (in)	Snowmelt for imp=30	Assumed Snowmelt TSS conc (mg/l)	TSS lbs	Runoff cfs	TSS Concentration mg/l	Rainfall Runoff in	Snowmelt Runoff in	Runoff cfs
	8-Aug	0.11			0	0.000	n/a	0.00		0.000
	13-Aug	0.15			0	0.000	n/a	0.00		0.000
	15-Aug	0.52			5	0.008	116	0.03		0.006
	17-Aug	0.24			1	0.001	140	0.00		0.000
	24-Aug	0.54			1	0.001	138	0.00		0.000
	7-Sep	0.11			0	0.000	n/a	0.00		0.000
	8-Sep	0.15			0	0.000	172	0.00		0.000
	17-Sep	0.26			0	0.000	n/a	0.00		0.000
	18-Sep	0.33			2	0.003	128	0.00		0.000
	19-Sep	0.14			0	0.000	181	0.00		0.000
	25-Sep	0.17			0	0.000	n/a	0.00		0.000
	30-Sep	0.13			0	0.000	n/a	0.00		0.000
	1-Oct	0.16			0	0.000	166	0.00		0.000
	2-Oct	0.31			2	0.002	130	0.00		0.000
	3-Oct	0.19			0	0.000	153	0.00		0.000
	28-Oct	0.18			0	0.000	n/a	0.00		0.000
	29-Oct	0.1			0	0.000	n/a	0.00		0.000
	31-Oct	0.3			2	0.002	131	0.00		0.000
24	27-Nov		0.03	43	0	0.002	43		0.00	0.001
25	28-Nov		0.03	40	0	0.002	40		0.00	0.001
22	13-Dec		0.03	48	0	0.002	48		0.00	0.001
23	14-Dec		0.03	45	0	0.002	45		0.00	0.001
	Total	6.67			45					0
	Median Day	0.20			1	0.002	81	0.00	0.00	0
	Rain	6.67			16	0.000	140	0.03		0
	Snowmelt				29	0.00	70		0.2	0
	Maximum Summer Day				4.82	0.008	251	0.03	0.01	0.01
	Minimum Overall				0.00	0.00	0	0.00	0.00	0.00
	TSS - Winter % of Total				64%					89%

Rainfall Runoff TR 55 CN Values for Juneau and Bethel

MONTGOMERY WATSON

BY ______ DATE ______ CLIENT ______ SHEET ______ OF ______
CHKD. BY ______ DESCRIPTION ______ JOB NO. ______

TR-55 APPLIED TO JUNEAU + BETHEL

A. JUNEAU

Assume hydrologic soil group C

Undeveloped conditions w/fair brush CN = 70 AMC II
Table 2.2c Table 2.2c

CN = 85 AMC III
Table 10.1

Antecedent Moisture Conditions:
AMC II - average
AMC III - upper limit of moisture

Developed conditions		AMC II	AMC III **
Residential	1/4 ac lots	83	93
Commercial	85% imp	94 *	98
Industrial	50% imp	86 *	94

* interpolated from table 2.2a
** Table 10.1

B. Bethel

Assume hydrologic Soil Group D

undeveloped AMC II CN = 73
AMC III CN = 87

developed

residential AMC II CN = 85
AMC III CN 94

commercial AMC II CN = 87
AMC III CN = 95

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United States
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Conservation
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Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

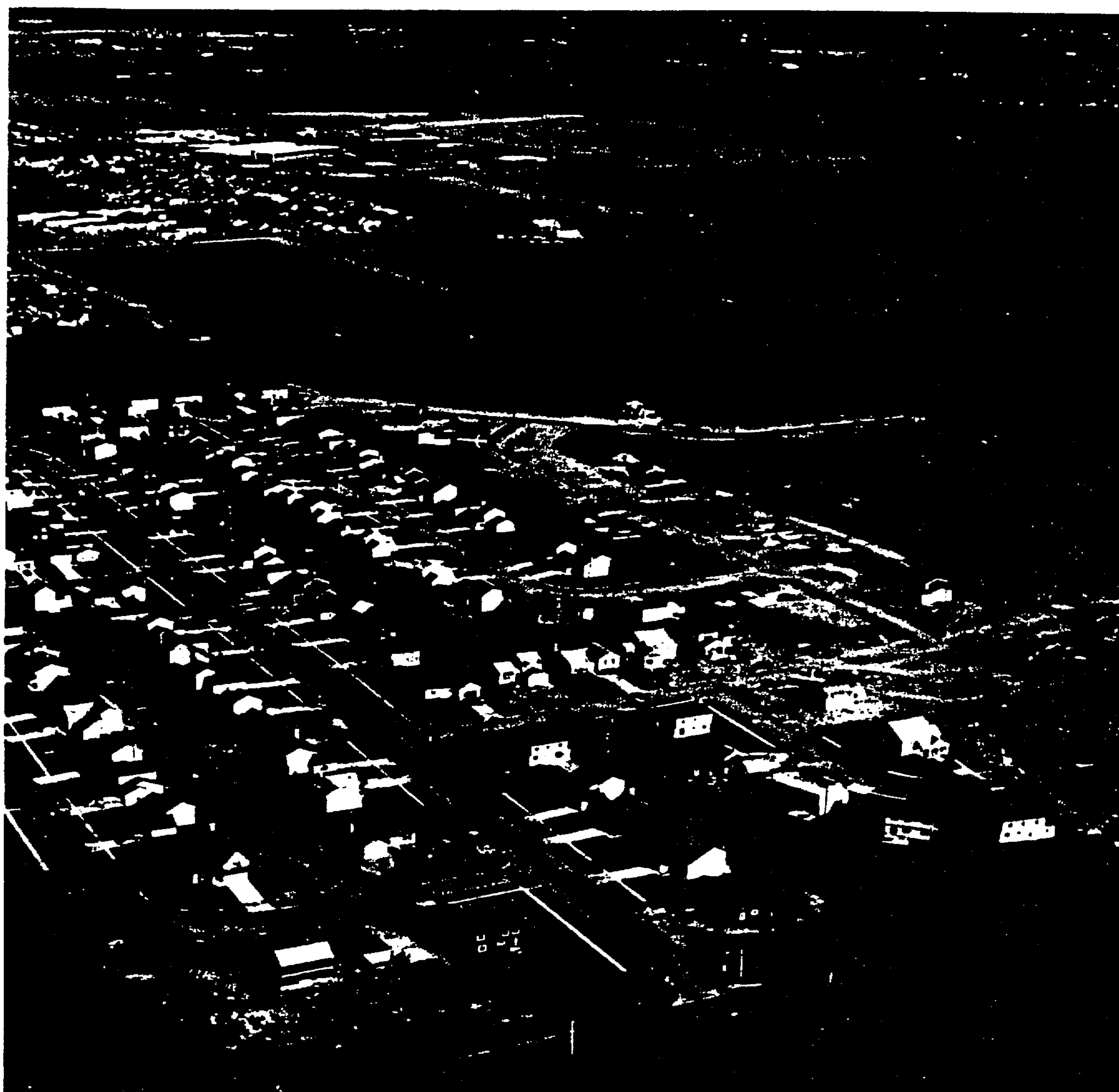

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

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National Engineering Handbook

Section 4

Hydrology

Table 10.1. Curve numbers (CN) and constants for the case $I_a = 0.2$ S

1	2	3	4	5	1	2	3	4	5
CN for condi-tion II	CN for conditions I	III	S values*	Curve* starts where P =	CN for condi-tion II	CN for conditions I	III	S values*	Curve* starts where P =
			(inches)	(inches)				(inches)	(inches)
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	.101	.02	59	39	77	6.95	1.39
98	94	99	.204	.04	58	38	76	7.24	1.45
97	91	99	.309	.06	57	37	75	7.54	1.51
96	89	99	.417	.08	56	36	75	7.86	1.57
95	87	98	.526	.11	55	35	74	8.18	1.64
94	85	98	.638	.13	54	34	73	8.52	1.70
93	83	98	.753	.15	53	33	72	8.87	1.77
92	81	97	.870	.17	52	32	71	9.23	1.85
91	80	97	.989	.20	51	31	70	9.61	1.92
90	78	96	1.11	.22	50	31	70	10.0	2.00
89	76	96	1.24	.25	49	30	69	10.4	2.08
88	75	95	1.36	.27	48	29	68	10.8	2.16
87	73	95	1.49	.30	47	28	67	11.3	2.26
86	72	94	1.63	.33	46	27	66	11.7	2.34
85	70	94	1.76	.35	45	26	65	12.2	2.44
84	68	93	1.90	.38	44	25	64	12.7	2.54
83	67	93	2.05	.41	43	25	63	13.2	2.64
82	66	92	2.20	.44	42	24	62	13.8	2.76
81	64	92	2.34	.47	41	23	61	14.4	2.88
80	63	91	2.50	.50	40	22	60	15.0	3.00
79	62	91	2.66	.53	39	21	59	15.6	3.12
78	60	90	2.82	.56	38	21	58	16.3	3.26
77	59	89	2.99	.60	37	20	57	17.0	3.40
76	58	89	3.16	.63	36	19	56	17.8	3.56
75	57	88	3.33	.67	35	18	55	18.6	3.72
74	55	88	3.51	.70	34	18	54	19.4	3.88
73	54	87	3.70	.74	33	17	53	20.3	4.06
72	53	86	3.89	.78	32	16	52	21.2	4.24
71	52	86	4.08	.82	31	16	51	22.2	4.44
70	51	85	4.28	.86	30	15	50	23.3	4.66
69	50	84	4.49	.90					
68	48	84	4.70	.94	25	12	43	30.0	6.00
67	47	83	4.92	.98	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	82	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	5.87	1.17	0	0	0	infinity	infinity
62	42	79	6.13	1.23					
61	41	78	6.39	1.28					

*For CN in column 1.

Derivation of Snowmelt Runoff and TSS Loading from North Arctic/Orbit Data

DETERMINE SNOWMELT RUNOFF +
TSS LOADING

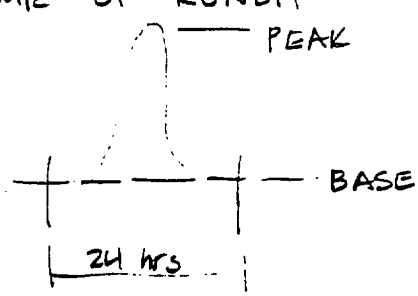
BASED ON 1988 DATA FROM 2 RESIDENTIAL BASINS
(BILLMAN + BACON, 1990)

A. DERIVE DAILY RUNOFF - inches - FROM SPRING
SNOWMELT RUNOFF RECORD

PICK DAILY BASE FLOW + PEAK FLOW N CFS

1. COMPUTE DAILY VOLUME OF RUNOFF

ASSUMPTIONS:



$$VOL\,(ft^3) = \left[Q_{base}(cfs) \cdot 24\,hrs + \left(Q_{peak} - Q_{base}\right)\left(\frac{10\,hrs}{2}\right) \right] \times 3600\,\frac{sec}{hr}$$

$$= \left(19\,Q_{base} + 5\,Q_{peak}\right) cfs \times 3600\,\frac{sec}{hr} = VOL\,(ft^3)$$

2. COMPUTE VOLUME IN INCHES

$$VOL(in) = \frac{VOL\,(ft^3)}{basin\ area\ (ac)} \times \frac{ac}{43560\,ft^2} \times \frac{12\ in}{ft}$$

2. DERIVE DAILY TSS LOADING lbs/ac/in runoff
FROM SPRING TSS in SNOWMELT RUNOFF DATA

Q_i (cfs) = INSTANTANEOUS FLOW AT TIME WHEN TSS SAMPLED

TSS_i ($\frac{mg}{l}$) = TSS SAMPLE CONCENTRATION

3. DETERMINE RATIO:

$$R = \frac{\text{VOL IF } Q_i \text{ CONTINUED FOR 24 HRS}}{\text{VOL OF RUNOFF FOR DAY}} = \frac{24\ Q_i}{19\,Q_{base} + 5\,Q_{peak}}$$

4. ASSUME TSS CONC $\propto$ VELOCITY
VELOCITY $\propto$ DISCHARGE

SO TSS CONC $\propto$ DISCHARGE

THEN $TSS_{AVG} = TSS_i\,[R]$ $\frac{mg}{l}$

5. COMPUTE $Q_{AVG} = \frac{(19\,Q_{base} + 5\,Q_{peak})}{24 \text{ hrs}}$ cfs

6. COMPUTE $\frac{lbs}{day}$ TSS $= Q_{AVG} \times TSS_{AVG} \times 5.401$ *

7. COMPUTE TSS (lb/ac/in) = $\frac{lb}{day}$ TSS $\div$ acres $\div$ in runoff

ONLY HAD 4 DATA PTS FOR TSS LOADING, BUT
30 DAYS OF SNOW MELT RUNOFF

DETERMINE SOME RELATIONSHIP OVER TIME FOR ESTIMATING
DAILY TSS → NEXT PAGE

* CONVERSION

$$\left[Q\ \frac{ft^3}{sec} \times TSS\ \frac{mg}{l}\right] \times \frac{3.785\,l}{gal} \cdot \frac{7.49\,gal}{ft^3} \cdot \frac{kg}{10^6\,mg} \times \frac{2.205\,lbs}{kg} \times \left. 3600 \times 24\ \frac{sec}{day}\right] = Q \cdot conc \cdot 5.4$$

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.30	616	.19	700
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.07	48	.08	26
[illegible]	35	[illegible]	[illegible]	[illegible]	[illegible]	.22	[illegible]	.05	20
[illegible]	41	[illegible]	[illegible]	1	[illegible]	.20	20	[illegible]	16

% IMP: 30.5 37

LET $\frac{mg}{l}$ = f(day of snowmelt) = f(d_i)

REGRESSION ANALYSIS

	N. ARCTIC	ORBIT	AVG
R^2	.98	.91	
intercept	195	238	217
coeff	-4.67	-6.23	-5.43

[illegible] USE RESULTING EQN TO PREDICT SNOWMELT TSS CONC

$$TSS\left(\frac{mg}{l}\right) = 217 - 5.48\, d_i$$

MONTGOMERY WATSON

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SNOWMELT RUNOFF AS AFFECTED BY % IMP

1988 Data from Bi'man & Bacon

	N Arctic	Orbit	Relative % Diff (RPD)
Area	47.9 ac	18.78 ac	
% imp	30.5	37	(37 - 30.5)/30.5 = 21.3%
Σ Runoff 3-17 to 4-?-83	1.68"	2.76"	(2.76 - 1.68)/1.68 = 64.3%

So, for each 1% impervious > 30%,

Runoff increases by $\left(\frac{64.3}{37-30.5}\right)$ = 10%

FOR % IMP = 70, THIS WOULD BE (40 x 10%) = 400%

THIS SEEMS UNREASONABLY HIGH

CHECK USING DATA from USGS CHESTER CK REPORT p 24 (Brabets 1987)

	SBSF Trib	36th Av Trib	RPD
Area	9.6 ac	38.4 ac	
% imp	30 %	70%	133%
Σ Runoff 3-7 to 3-14-84	.55"	1.15"	109%

For Each 1% imp > 30%, Runoff increases by $\left(\frac{109}{40}\right)$ = 2.7%

CONCLUSION → USE 3% increase/decrease in snowmelt runoff for each 1% increase/decrease in impervious

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BY ______ DATE ______ CLIENT ______ SHEET 5 OF 5

CHKD. BY ______ DESCRIPTION ______ JOB NO. ______

TO PREDICT RUNOFF [illegible] IMPERVIOUS [illegible]

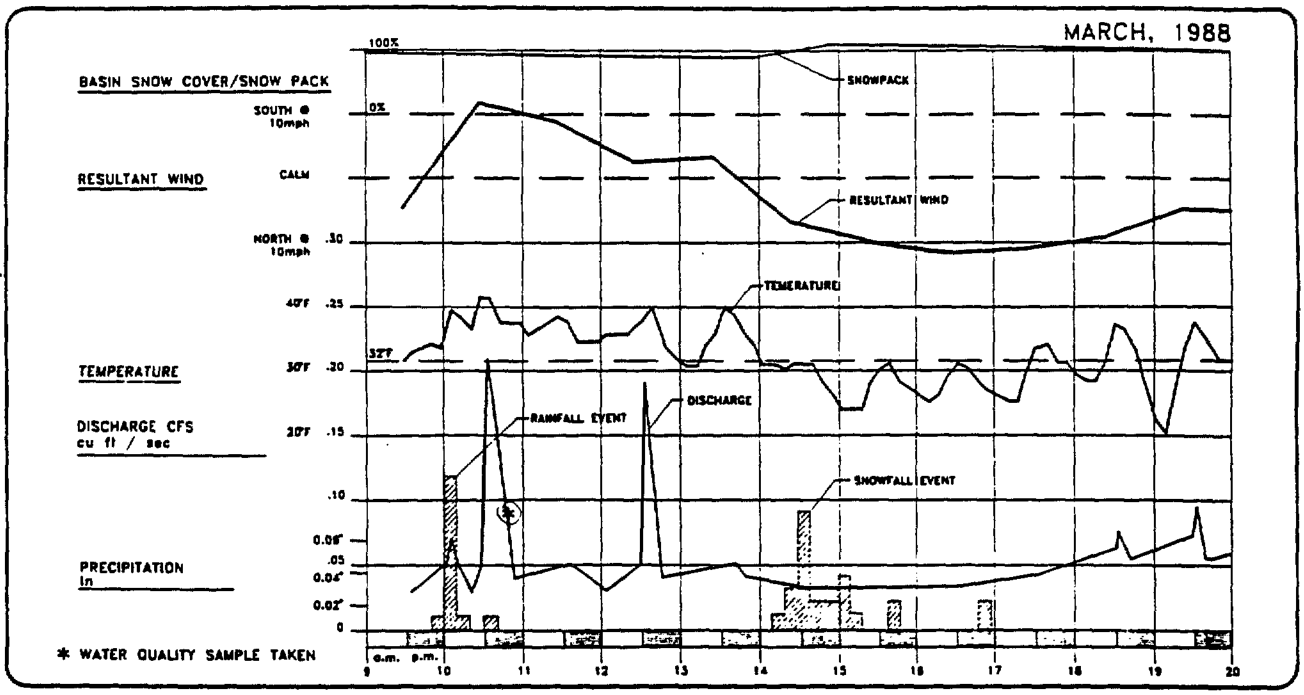
LET VOL_{30} = DAILY RUNOFF VOLUME [illegible]

[illegible]

LET PIA = Percent impervious area of different basin, fraction

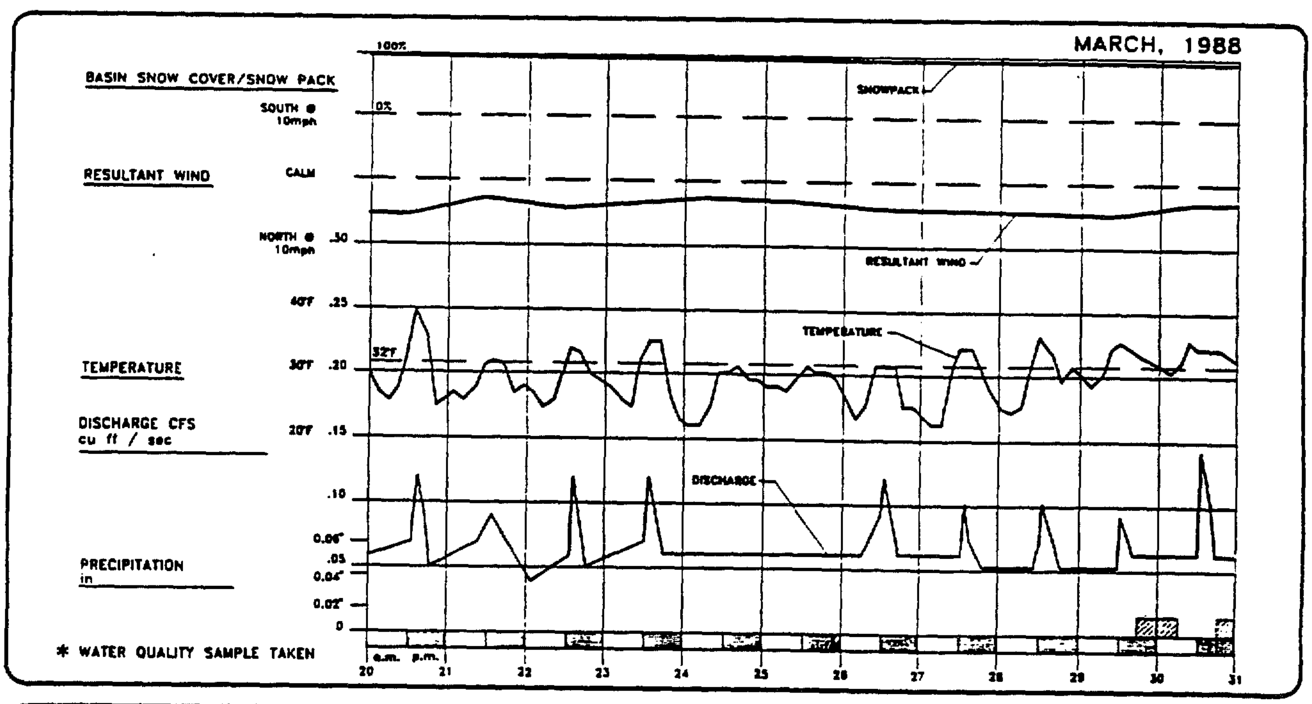
VOL = Volume of runoff in different basin (in)

THEN $VOL = VOL_{30}(1 + (PIA - .30) \times .03)$



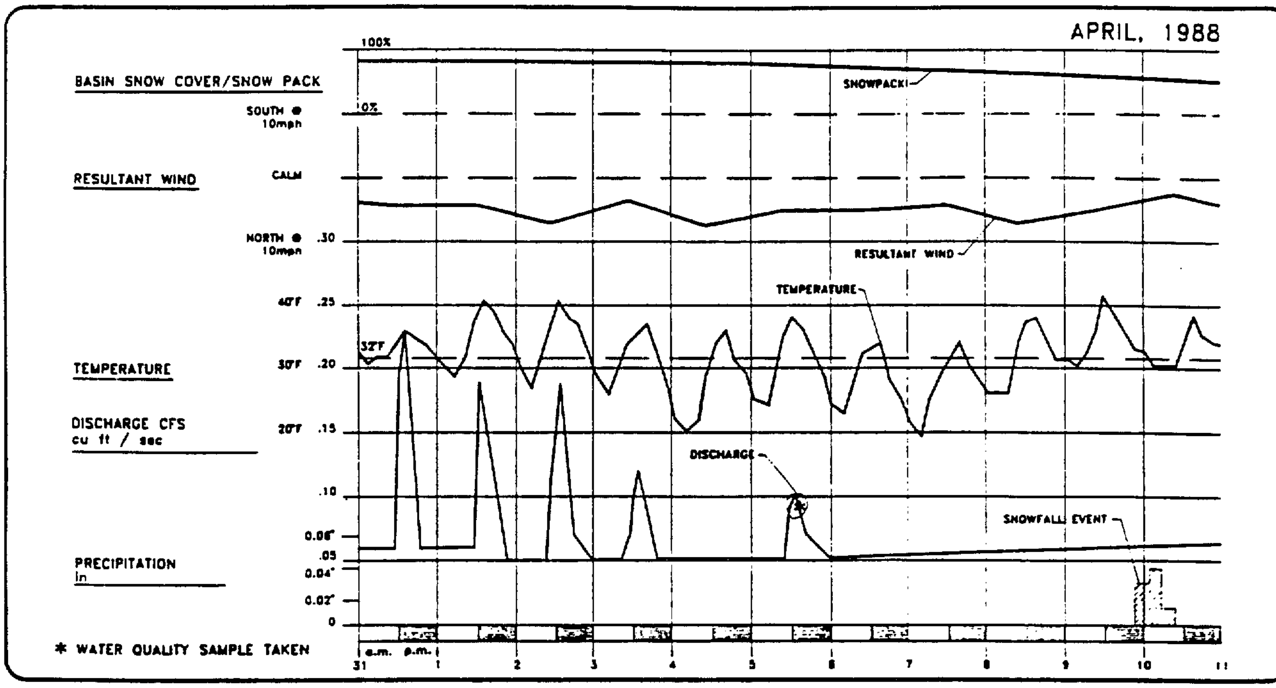
BREAKUP HYDROGRAPH
FOR
ORBIT BASIN

FIGURE
10



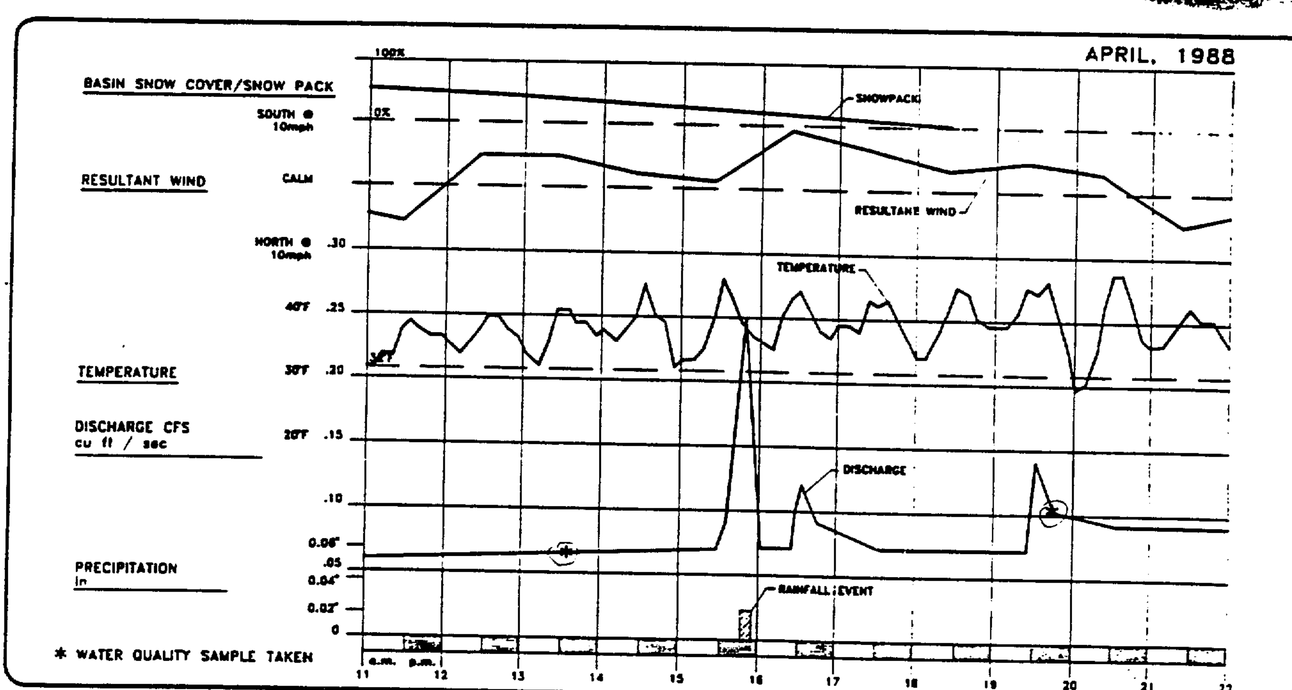
BREAKUP HYDROGRAPH
FOR
ORBIT BASIN

FIGURE
11



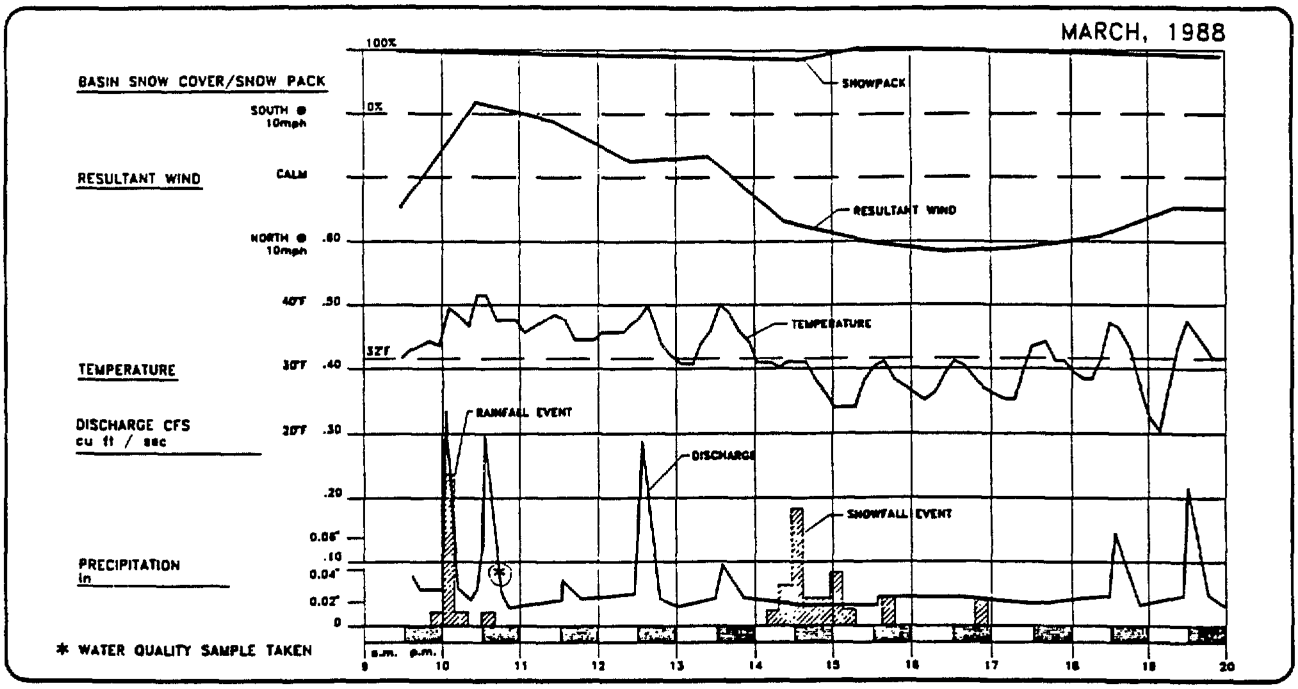
BREAKUP HYDROGRAPH FOR ORBIT BASIN

FIGURE 12



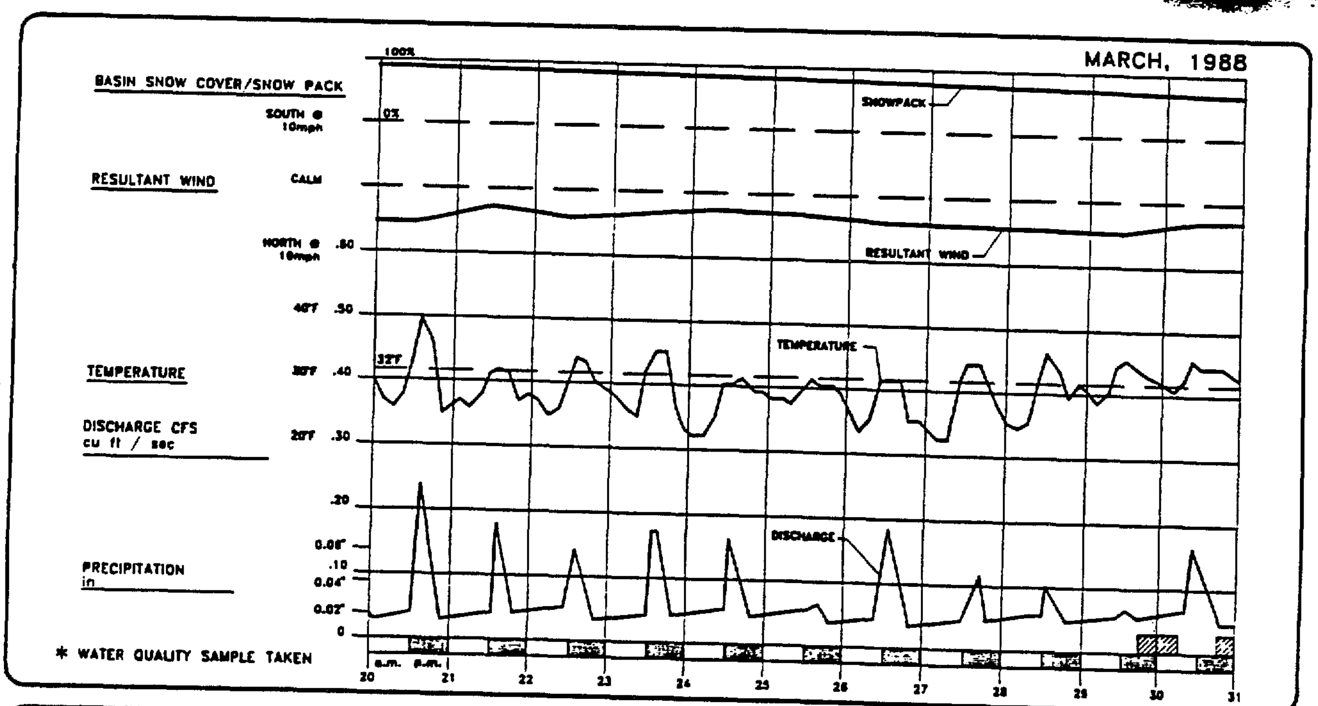
BREAKUP HYDROGRAPH FOR ORBIT BASIN

FIGURE 13



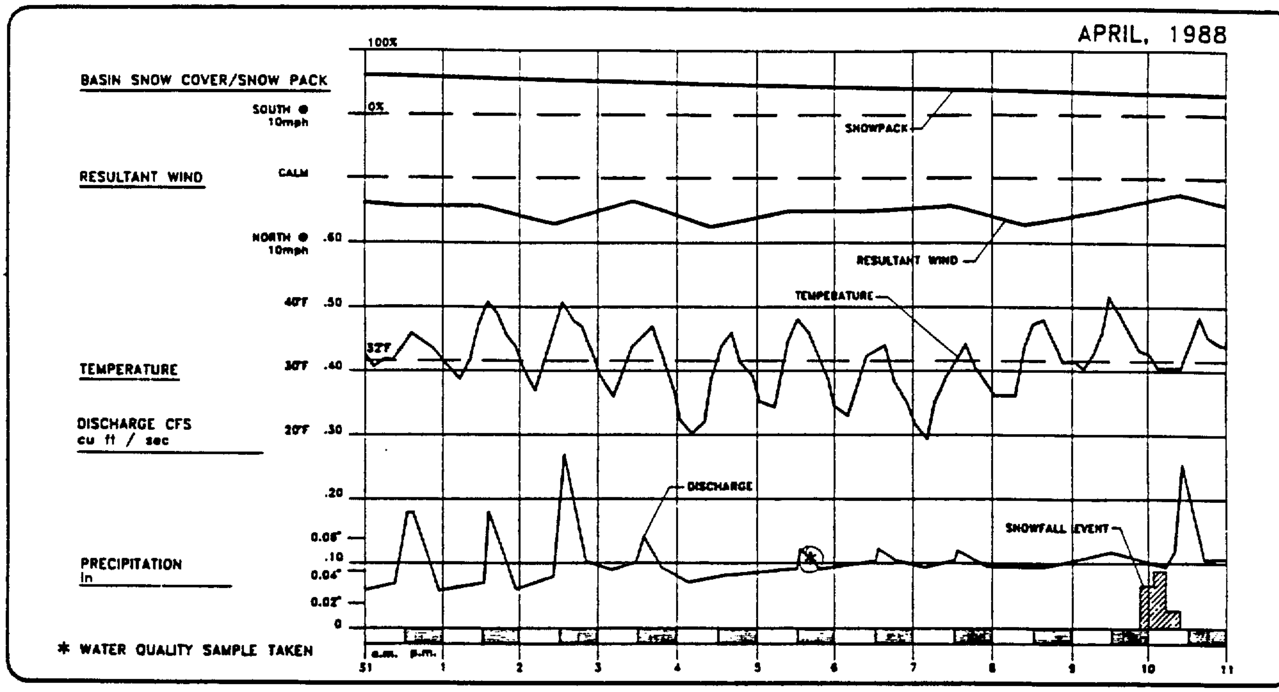
BREAKUP HYDROGRAPH FOR NORTH ARCTIC BASIN

FIGURE 6



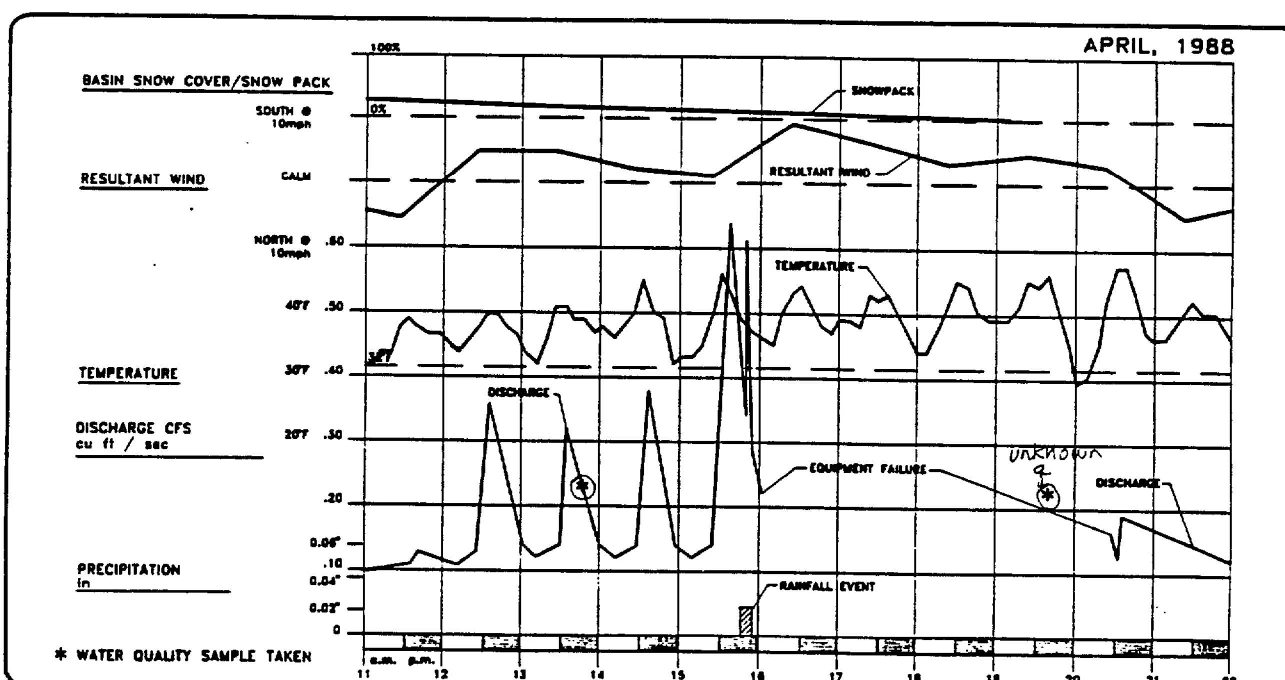
BREAKUP HYDROGRAPH FOR NORTH ARCTIC BASIN

FIGURE 7



BREAKUP HYDROGRAPH
FOR
NORTH ARCTIC BASIN

FIGURE
8



BREAKUP HYDROGRAPH
FOR
NORTH ARCTIC BASIN

FIGURE
9

Derivation of Annual Predevelopment TSS Based on Universal Soil Loss Equation

MONTGOMERY WATSON

BY [illegible] DATE [illegible] CLIENT DCG SHEET 1 OF 7

CHKD. BY ______ DESCRIPTION PREDEVELOPMENT SOIL LOSS JOB NO. 4379.00

JUNEAU
PREDEVELOPMENT + POST
TSS LOADING

Ref: Goldman, S, K Jackson, T Bursztynsky
Erosion + Sedimentation Control Handbook
1986 McGraw Hill

ASSUMPTION: SOIL LOSS = TSS LOAD

3 SITE SIZES: 5 AC
5 AC
20 AC

UNIVERSAL SOIL LOSS EQUATION

- This eqn gives annual loading
- it has been calibrated for [illegible] conditions
  ~~250~~ agr cultural land

$A = R \cdot K \cdot LS \cdot C \cdot P$

A - tons/ac-yr
for [illegible]

R - rainfall erosion [illegible] $\frac{ton}{ac} \cdot \frac{in}{hr}$

K erodibility $\frac{ton}{ac \cdot R}$

LS slope length + steepness factor

C vegetative cover

P erosion control factor

$R \cong 50$ for PAC NW Fig 5.2 p 5.8
Alternately

$R = c_i\, p^{2.2}$ where $c_i = f$(storm type)
p = 2 yr 6 hr storm

For Juneau -
Assume Type IA storm type

$R = 10.2\, p^{2.2}$ where p = 2yr 6hr rainfall

IF $\underline{R = 50} = 10.2\, p^{2.2}$: is calculated p reasonable?

$\ln \frac{50}{10.2} = 2.2 \ln p$

$p = \exp\left[\frac{1}{2.2} \ln \frac{50}{2.2}\right] = \underline{\underline{2.1}}"$ OK
per Miller 1963

MONTGOMERY WATSON

BY ______ DATE ______ CLIENT ______ SHEET 2 OF 7

CHKD. BY ______ DESCRIPTION ______ JOB NO. ______

JUNEAU [illegible]

K based on soil survey or sieve analysis data

We have neither

Choose HeA soil type - fine sandy loam from SCS Soils of the Juneau Area

assume sand 60
silt 30
clay 12

from [illegible] p 5.15 k = .29

LS factor HeA on 0-3% slopes on a 10 ac site

say 3%

		LS (Table 5.5 p 5.20)
for 5 Ac site	l = 660	.33
15	1140	.41 *
20	1320	.43 *

$\Sigma A\ ft^2$

$d = \sqrt{A}$

* EXTRAPOLATED $l = \sqrt{A \cdot 2}$

Cover C factor

"Native vegetation" c = 0.01 Table 5.6 p 5.23

P let P = 1 p 5.24

So A = 50 x .29 x .33 x .01 x 1 = .05 T/ac = 96 lbs/ac for 5 ac
= .41 = 119 lbs/ac 15 ac
.43 = 125 lbs/ac 20 ac

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MONTGOMERY WATSON

BY ____________ DATE __________ CLIENT ______________________________ SHEET 3 OF 7

CHKD. BY ________ DESCRIPTION ______________________________ JOB NO. ______________

[illegible] SOIL LOSS - [illegible]

RESIDENTIAL [illegible] lbs/ac × 5 ac = [illegible] lbs/yr

COMMERCIAL [illegible] lbs/ac × [illegible]5 ac = [illegible]35 lbs/yr

INDUSTRIAL 125 lbs/ac × 20 ac = 2500 lbs/yr

Anchorage ... 'bad' - pre development

2 SITE SIZES 5 AC
10 AC

based on USLE $A = R \cdot K \cdot LS \cdot C \cdot P$

CHOOSE SOIL TYPE IN MIDTOWN <u>CmA</u>

R P (2 yr 6 hr) = 0.66" per MOA Design Criteria
assume Type I storm
$R = 16.55\ P^{2.2}$

$= 16.55\ (.66)^{2.2} = 6.5$

K from Anchorage Soil Survey p 78

K = .43

LS ASSUME 2% SLOPE 5 AC $L = 660$ LS = .35
10 AC $l = 930$ LS = .39

Table 5.4 p 5.18

C = .01 native vegetation p 5.23

P = 1 p 5.24

$A \left(\frac{\text{tons}}{\text{yr}}\right) = R \cdot K \cdot LS \cdot C \cdot P$

5 Acres $= 6.5 \times .43 \times .35 \times .01 \times 1 = .01\ T/yr\text{-}ac = 20\ \text{lbs}/\text{ac-yr}$
10 Ac $6.5 \times .43 \times .39 \times .01 \times 1 = 22\ \text{lbs}/\text{ac yr}$

CHECK 1 other Soil type <u>TuB</u>

R, C, P all the same

K = .43 for TuB S = 3 - 7%

LS Use S = 5% : L = 930' LS = 1.63
L = 660 LS = 1.38

$A = 6.5 \times .43 \times 1.63\ (1.38) \times .01 \times 1 = .05\ T/ac\text{-}yr = 90\ \text{lbs/ac-yr}$ 10ac
77 lbs/ac-yr 5ac

MONTGOMERY WATSON

BY ____ DATE 6-23-95 CLIENT ____ SHEET 5 OF 7

CHKD. BY ____ DESCRIPTION ____ JOB NO. ____

For Anchorage

"undisturbed" soil loss ranges

		CnA	Tu3	AVERAGE	
5	AC	20	77	48 lbs/ac-yr ×5 ac =	$\boxed{240\ \text{lbs/yr}}$
10	AC	22	90	60 lbs/ac-yr ×10 ac	$\boxed{600\ \text{lbs/yr}}$

USE

MONTGOMERY WATSON

BY ________ DATE 6-24-95 CLIENT ________ SHEET 6 OF 7

CHKD. BY ________ DESCRIPTION ________ JOB NO. ________

USLE in BETHEL PREDEVELOPMENT

A (ton/ac-yr) = R · K · LS · C · P

2 SITE SIZES: 1 Ac
5 Ac

R depends on precip or curves developed
no curves in SW AK
So use precip function
Assume Type I storm

then $R = 16.55\, p^{2.2}$ for p = 2-yr 6-hr rainfall

p = 1.0 inches for Bethel (from TP-47)
* NOTE – THIS IS PROBABLY HIGH
So R = 16.55
ANC USES 2.66" ; similar rainfall patterns

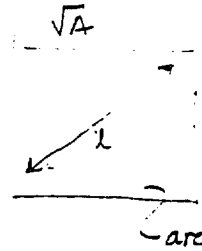
K depends on soils – no erodibility factor in soils report

use Kuskokwim-Kw assoc – silt

assume gradation %: sand 10
silt 80
clay 10

from Figure 5.3 p 5.5 K = .61

LS Assume S = 1% (Bethel is pretty flat)
l (5 ac) = 660' LS = .18
(2ac) = 417' .16



$l = \sqrt{2(\sqrt{A})^2}$

C .01 for undisturbed cover p 5.23

P 1 p 524

A = 16.55 * .61 * {.18, .16} * .01 * 1 = .02 T/ac-yr = 36 lbs/ac-yr × 5 ac = 180 lbs/yr
= .02 T/ac-yr = 32 lbs/ac-yr × 1 ac = 32 lbs/yr

OTHER SOILS ARE SILTY, TOO, SO DON'T BOTHER W/ SECOND SOIL TYPE

* BUT, SHOULD TRY DIFFERENT R – SEE NEXT PAGE

MONTGOMERY WATSON

BY ____________ DATE __________ CLIENT DCG SHEET 7 OF 7

CHKD. BY _______ DESCRIPTION ______________________________ JOB NO. 4379.0010

USLE for BETHEL

same assumptions as before

EXCEPT : P = 0.7" for 2 yr 6 hr storm

$R = 16.55 (.7)^{2.2} = 7.55$

$A = 7.55 \times .61 \times \begin{Bmatrix} .18 \\ .16 \end{Bmatrix} \times .01 \times 1 = .01$ T/ac yr = 17 lbs/ac yr @ 5 ac
= 15 lbs @ 2 ac

SITE LOADING 17 lbs/ac-yr × 5 ac = 85 lbs/yr
× 2 ac = 30 lbs/yr

THIS CUTS LOADING IN HALF, BUT RAINFALL IS MORE REASONABLE

TRY @ S = 0.5%

LS - 2 Ac $l = 417$ LS = .13
LS - 5 Ac $l = 660$ LS = .14

5 AC $17 \frac{lbs}{ac \cdot yr} \left(\frac{.14}{.18}\right) = 13 \frac{lbs}{yr \cdot ac}$ ⇒ $\boxed{60\ lb/yr}$

2 AC $15 \frac{lbs}{y} \left(\frac{.13}{.16}\right) = 11 \frac{lbs}{ac \cdot yr}$ ⇒ $\boxed{23\ lb/yr}$

USE

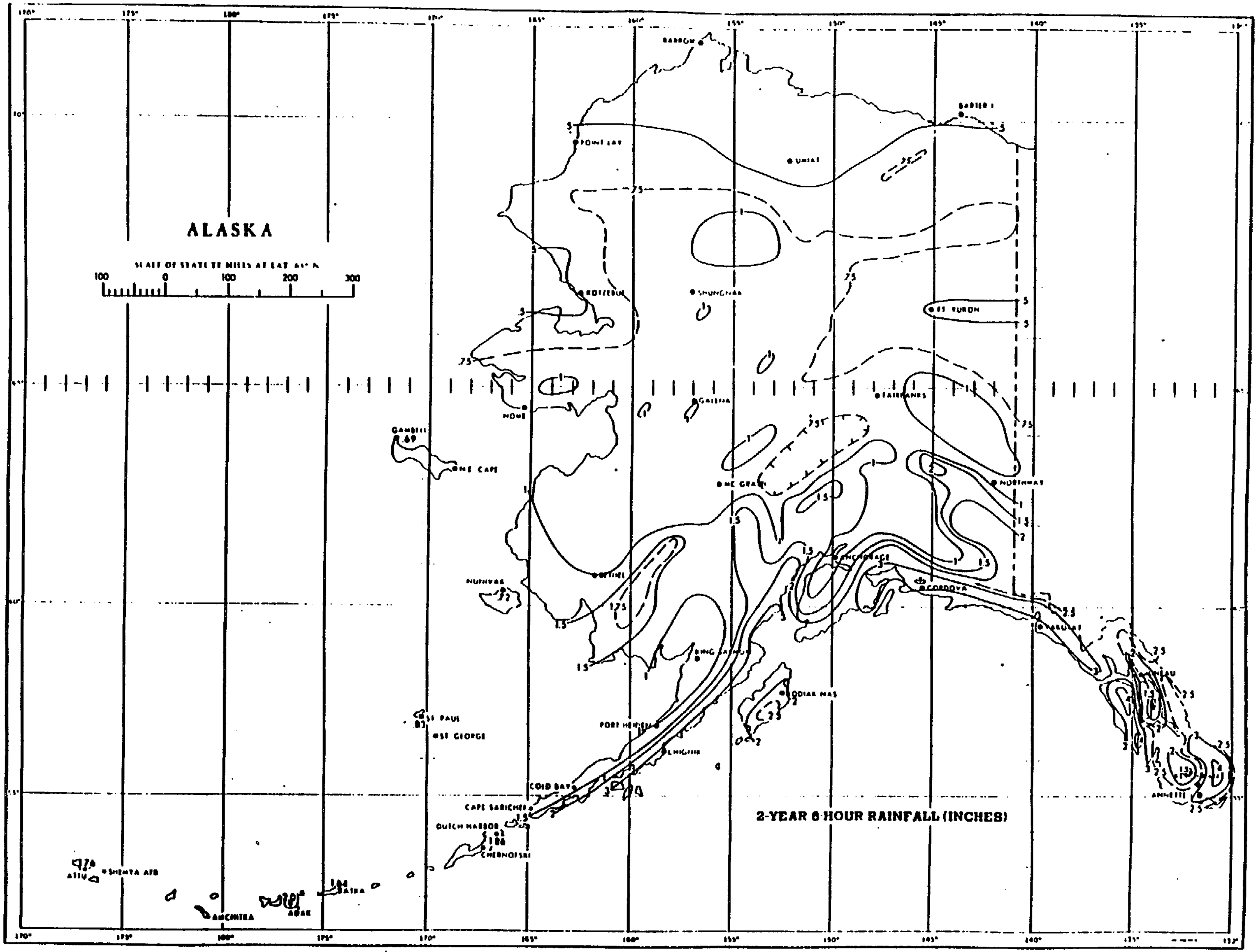


FIGURE 3-40.—2-yr. 6-hr. rainfall (in.).

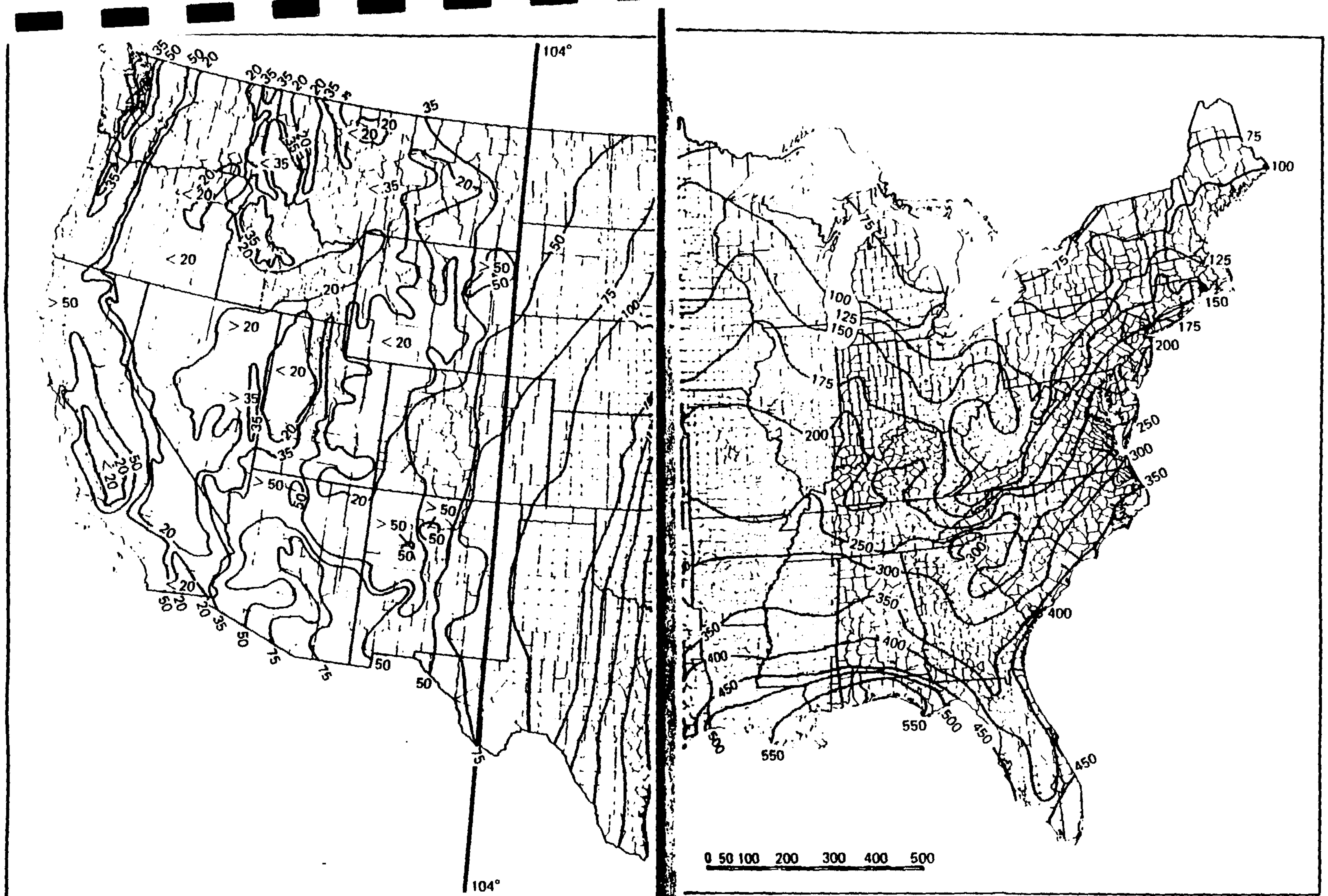


Fig. 5.2 *R* values for areas east of 104°. Because of irregular topography in the west United States, calculate *R* values in this region by using local rainfall data. *R* is in u of 100 ft · tons/acre per in/hr. To convert *R* to units of 10^7 J/ha per mm/hr, multipl 1.70. (20) Scale is in miles.

....e precise
for R is needed, other references (10, 20, 21) that explain how to calculate individual storms and years from local data should be consulted.
"isoerodent" map, prepared by Wischmeier for the USDA (20) and shown . 5.2, is used to find the R value for sites east of the Rocky Mountains ›ximately 104° west longitude). R can be interpolated for points between ıes. Contact local soil conservation service offices for more detailed infor- ı on R values in areas covered by this map. West of the 104th west merid- regular topography makes use of a generalized map impractical. For the n states, R is calculated by using rainfall data. Results of investigations at

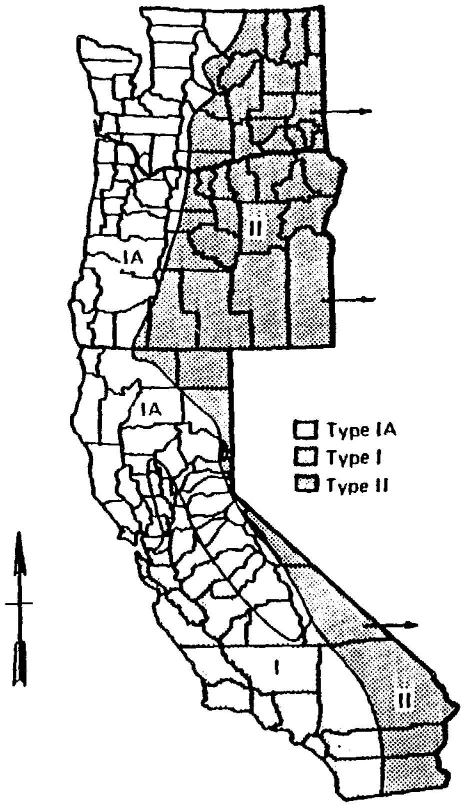


Fig. 5.3 Distribution of storm types in the western United States. (4) Type II storms occur in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming also.

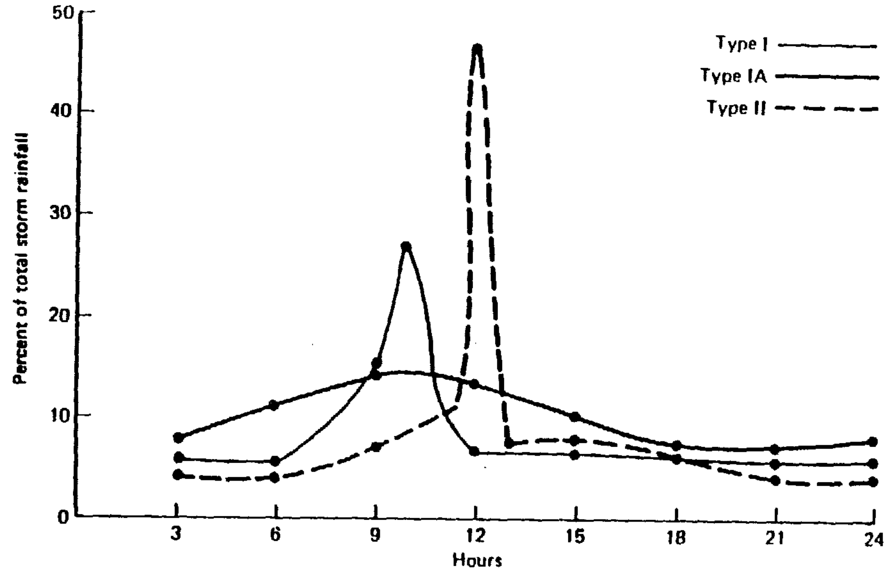


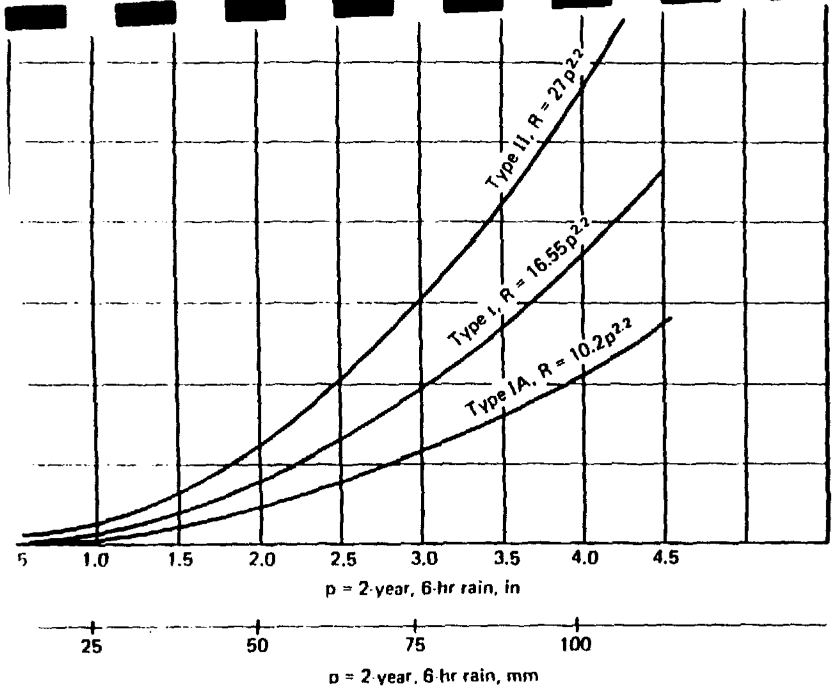
Fig. 5.4 Time distribution of rainfall within storm types. Adapted from unpublished data provided by Wendell Styner, U.S. Department of Agriculture, Soil Conservation Service, West Technical Service Center, Portland, Oregon, October 28, 1981.

the Runoff and Soil Loss Data Center at Purdue University showed that R values in the western states could be approximated with reasonable accuracy by using 2-year, 6-hr rainfall data. (20) Regression equations for three different storm types (I, IA, and II) are used to calculate R values. Figure 5.3 shows the distribution of type I, IA, and II storms throughout the western states.

A storm type is distinguished by the rainfall distribution within the storm. Figure 5.4 illustrates the time distributions of rainfall within the three types of storms. A type II storm is characterized by gradually increasing rainfall followed by a strong peak in rainfall intensity that tapers off to low-intensity rain. Type II storms occur in the following areas:

- The eastern parts of Washington, Oregon, and California (east of the Sierra Nevada)
- All of Idaho, Montana, Nevada, Utah, Wyoming, Arizona, and New Mexico

Type I and IA storms occur in a maritime climate. Type I is typical of storms that occur in southern and central California. These storms have a milder but definite peak similar to that of the type II storms. Type IA storms, which are characteristic of storms in coastal areas of northern California, Oregon, Washington, and the western slopes of the Sierra Nevada, have a low broad peak in the rainfall distribution.



.5 Relations between average annual erosion index and 2-year, 6-hr rainfall in nia. (14)

e differences in peak intensity are reflected in the coefficients of the equa- or the rainfall factor. Figure 5.5 is a graphical representation of the equa- The equations, also shown on the curves for each individual storm type,

$$R = 27p^{2.2} \qquad \text{type II}$$
$$R = 16.55p^{2.2} \qquad \text{type I}$$
$$R = 10.2p^{2.2} \qquad \text{type IA}$$

p is the 2-year, 6-hr rainfall in inches. (If p is in millimeters, the equations e: $R = 0.0219p^{2.2}$, type II; $R = 0.0134p^{2.2}$, type I; $R = 0.00828p^{2.2}$, type

R value is rounded to the nearest whole number. When the rainfall time ution curves (Fig. 5.4) and the corresponding R value equations are com- it is evident that the stronger the peak intensity of the typical storm, the the rainfall erosion index.

Find: The average annual R value for Sacramento, California.

Given: The 2-year, 6-hr rainfall is 1.2 in (30.5 mm).

Solution: Sacramento is in the type I storm area. Thus

$$R = 16.55p^{2.2} \qquad [0.0134 \times (p, \text{ in mm})^{2.2}]$$
$$\text{where } p = 1.2 \text{ in (30.5 mm)}$$
$$R = 24.72, \text{ or } 25$$

The rainfall erosion index does not account for erosion caused by snowmelt runoff. In any area where snow accumulates and the soil freezes, snowmelt runoff increases erosion losses. Until researchers develop a predictive method for this type of erosion, an addition component of the R value, termed R_s, should be added to the rainfall erosion index to determine a total R factor R_t. R_s is estimated by multiplying the average total winter precipitation (December through March) in inches (mm/25.4) of water by 1.5 [(mm/25.4) × 1.5 = 0.059 × mm].

EXAMPLE 5.2 Consider a site that has an R factor of 25 and receives 16 in (406 mm) of precipitation during the four winter months:

$$R_s = 1.5(16 \text{ in}) = 24 \qquad [0.059(406 \text{ mm}) = 24]$$
$$R_t = R + R_s$$
$$= 25 + 24$$
$$= 49$$

The R value is used to estimate the average annual soil loss. If erosion protection is required for less than one year, the soil loss for a portion of a year can be estimated by using a derivative of the R value. Since R is proportional to rainfall, the R value for a short time period can be calculated by multiplying the average rainfall during the shorter time period by the annual R value and dividing the product by the average annual rainfall. For example, suppose you wish to estimate soil loss in January. January rainfall averages 2 in (51 mm), and annual rainfall averages 20 in (510 mm). Then

$$R_{\text{Jan.}} = \frac{2 \text{ in}}{20 \text{ in}} \times R_{\text{annual}} \qquad \left(\frac{51 \text{ mm}}{510 \text{ mm}} \times R_{\text{annual}}\right),$$

EXAMPLE 5.3

Given: A site in California on the western slope of the Sierra Nevada where 2-year, 6-hr rainfall is 1.6 in (41 mm), December–March precipitation is 27.6 in (701 mm), and the storm type is IA.

Find: R, R_s, and R_t.

$$R = 10.2p^{2.2} = 28.7$$
$$R_s = 1.5(27.6\ \text{in}) = 41.4 \qquad [0.059(701\ \text{mm}) = 41.4]$$
$$R_t = R_s + R = 28.7 + 41.4 = 70.1$$

Soil Erodibility Factor K

›il erodibility factor K is a measure of the susceptibility of soil particles to ıment and transport by rainfall and runoff. Texture is the principal factor ıng K, but structure, organic matter, and permeability also contribute. K ; range from 0.02 to 0.69.

·eral methods can be used to estimate a K value for a site, but a nomograph ›d using analyses of site soils is the most reliable. If a recent soil survey for ea has been published and minimal soil disturbance is anticipated, the K listed in the survey of the soil series found on the site can be used.

›graph Method

referred method for determining K values is the nomograph method. Use nomograph requires a particle size analysis to determine the percentages ‹l, very fine sand, silt, and clay. The size range for each class is listed in 5.1. ASTM D-422 (1) is a standard hydrometer analysis for particle size ›ution. (Specific particle sizes can be designated in the request for analysis. typically, values are reported for specified size intervals, such as every 5 or . The fee for a particle size analysis is normally only a small fraction of the ee for a geotechnical report.)

› determination of the K value should be based on the soil exposed during ıtical rainfall months. Subsoils exposed during grading will have K values ›nt from the topsoil K value. On large sites, several samples should be and analyzed separately to ensure that differences in soil texture are ed. If fill is imported, this material also should be characterized.

› more carefully the site soils are characterized, the more accurate the K will be. If analysis indicates significant variation in soil erodibility, it be advisable to use different K values for different parts of the site and to ›rosion control efforts on the most susceptible areas. A simpler and more vative approach is to use the highest value obtained by analysis for all of the site, since it may not be possible to know exactly what soils will be ·d or how varied the soils are.

›omograph developed by Erickson of the SCS-Utah office (6), based on the ıl nomograph provided by Wischmeier (21), is reproduced in Fig. 5.6. To › nomograph, enter the triangle with any two of the particle size percents: ınd and silt; silt and clay; or clay and total sand. Use whole numbers. the dashed straight lines to their point of intersection. From that point, parallel to the dotted curves to the right side of the triangle, where the K are listed.

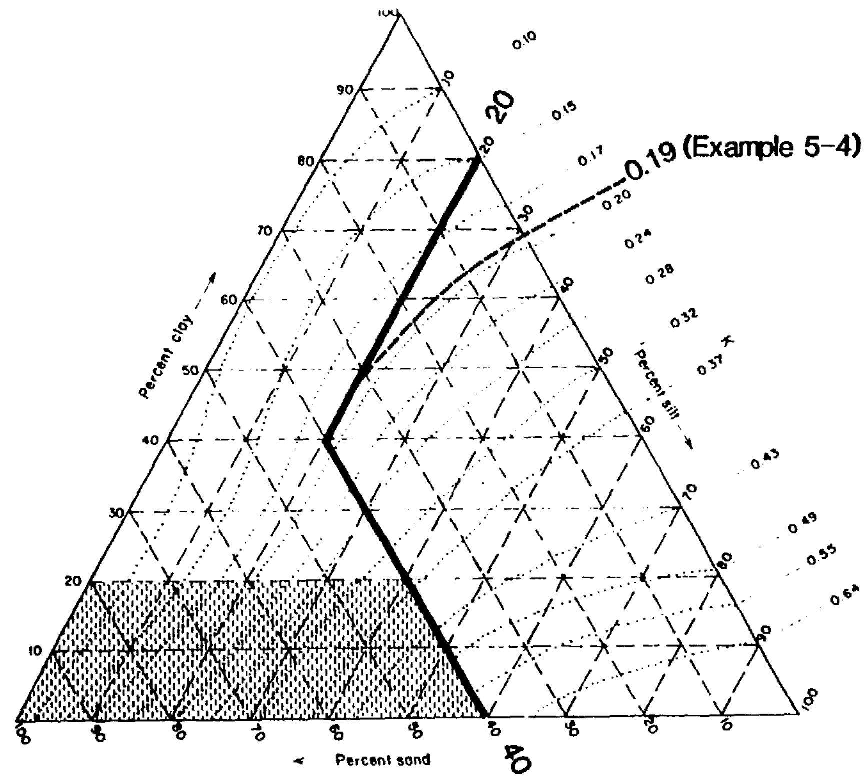


Fig. 5.6 Triangular nomograph for estimating K value. (6) See Table 5.3 for adjustments to K value under certain conditions.

EXAMPLE 5.4

Given: A soil with the following particle size distribution.

Component	Size, mm	Fraction, %
Sand	2.0–0.1	30
Very fine sand	0.1–0.05	10
Silt	0.05–0.002	20
Clay	Less than 0.002	40

Find: Texture and K value.

Solution: Entering Fig. 5.1 with 40 percent total sand and 20 percent silt, the texture is found to be on the border between clay and clay loam. Entering Fig. 5.6 with the same percents (see bold lines), the K value is found to be 0.19.

Table 5.3 describes adjustments to the K factor. Adjustment 1 is a correction for very

...ope ratio	gradient s, %	10 (3.0)	20 (6.1)	30 (9.1)	40 (12.2)	50 (15.2)	60 (18.3)	70 (21.3)	80 (24.4)	90 (27.4)	100 (30.5)
	0.5	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10
0:1	1	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12
	2	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20
	3	0.14	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.29
	4	0.16	0.21	0.25	0.28	0.30	0.33	0.35	0.37	0.38	0.40
:1	5	0.17	0.24	0.29	0.34	0.38	0.41	0.45	0.48	0.51	0.53
	6	0.21	0.30	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67
	7	0.26	0.37	0.45	0.52	0.58	0.64	0.69	0.74	0.78	0.82
:1	8	0.31	0.44	0.54	0.63	0.70	0.77	0.83	0.89	0.94	0.99
	9	0.37	0.52	0.64	0.74	0.83	0.91	0.98	1.05	1.11	1.17
:1	10	0.43	0.61	0.75	0.87	0.97	1.06	1.15	1.22	1.30	1.37
	11	0.50	0.71	0.86	1.00	1.12	1.22	1.32	1.41	1.50	1.58
:1	12.5	0.61	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92
	15	0.81	1.14	1.40	1.62	1.81	1.98	2.14	2.29	2.43	2.56
:1	16.7	0.96	1.36	1.67	1.92	2.15	2.36	2.54	2.72	2.88	3.04
:1	20	1.29	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08
:1	22	1.51	2.13	2.61	3.02	3.37	3.69	3.99	4.27	4.53	4.77
:1	25	1.86	2.63	3.23	3.73	4.16	4.56	4.93	5.27	5.59	5.89
	30	2.51	3.56	4.36	5.03	5.62	6.16	6.65	7.11	7.54	7.95
1	33.3	2.98	4.22	5.17	5.96	6.67	7.30	7.89	8.43	8.95	9.43
	35	3.23	4.57	5.60	6.46	7.23	7.92	8.55	9.14	9.70	10.22
1	40	4.00	5.66	6.93	8.00	8.95	9.80	10.59	11.32	12.00	12.65
	45	4.81	6.80	8.33	9.61	10.75	11.77	12.72	13.60	14.42	15.20
1	50	5.64	7.97	9.76	11.27	12.60	13.81	14.91	15.94	16.91	17.82
	55	6.48	9.16	11.22	12.96	14.48	15.87	17.14	18.32	19.43	20.48
1	57	6.82	9.64	11.80	13.63	15.24	16.69	18.03	19.28	20.45	21.55
	60	7.32	10.35	12.68	14.64	16.37	17.93	19.37	20.71	21.96	23.15
1	66.7	8.44	11.93	14.61	16.88	18.87	20.67	22.32	23.87	25.31	26.68
	70	8.98	12.70	15.55	17.96	20.08	21.99	23.75	25.39	26.93	28.39
	75	9.78	13.83	16.94	19.56	21.87	23.95	25.87	27.66	29.34	30.92
1	80	10.55	14.93	18.28	21.11	23.60	25.85	27.93	29.85	31.66	33.38
	85	11.30	15.98	19.58	22.61	25.27	27.69	29.90	31.97	33.91	35.74
	90	12.02	17.00	20.82	24.04	26.88	29.44	31.80	34.00	36.06	38.01
	95	12.71	17.97	22.01	25.41	28.41	31.12	33.62	35.94	38.12	40.18
1	100	13.36	18.89	23.14	26.72	29.87	32.72	35.34	37.78	40.08	42.24

LS values for following slope lengths l, ft (m)

gradient s, %	150 (46)	200 (61)	250 (76)	300 (91)	350 (107)	400 (122)	450 (137)	500 (152)	600 (183)	700 (213)	800 (244)	900 (274)	1000 (305)
0.5	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15
1	0.14	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20
2	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.39	0.40
3	0.32	0.35	0.38	0.40	0.42	0.43	0.45	0.46	0.49	0.51	0.54	0.55	0.57
4	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.82	0.87	0.92	0.96	1.00
5	0.66	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.31	1.42	1.51	1.60	1.69
6	0.82	0.95	1.06	1.16	1.26	1.34	1.43	1.50	1.65	1.78	1.90	2.02	2.13
7	1.01	1.17	1.30	1.43	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.61
8	1.21	1.40	1.57	1.72	1.85	1.98	2.10	2.22	2.43	2.62	2.80	2.97	3.13
9	1.44	1.66	1.85	2.03	2.19	2.35	2.49	2.62	2.87	3.10	3.32	3.52	3.71
10	1.68	1.94	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.11	4.33
11	1.93	2.23	2.50	2.74	2.95	3.16	3.35	3.53	3.87	4.18	4.47	4.74	4.99
12.5	2.35	2.72	3.04	3.33	3.59	3.84	4.08	4.30	4.71	5.08	5.43	5.76	6.08
15	3.13	3.62	4.05	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
16.7	3.72	4.30	4.81	5.27	5.69	6.08	6.45	6.80	7.45	8.04	8.60	9.12	9.62
20	5.00	5.77	6.45	7.06	7.63	8.16	8.65	9.12	9.99	10.79	11.54	12.24	12.90
22	5.84	6.75	7.54	8.26	8.92	9.54	10.12	10.67	11.68	12.62	13.49	14.31	15.08
25	7.21	8.33	9.31	10.20	11.02	11.78	12.49	13.17	14.43	15.58	16.66	17.67	18.63
30	9.74	11.25	12.57	13.77	14.88	15.91	16.87	17.78	19.48	21.04	22.49	23.86	25.15
33.3	11.55	13.34	14.91	16.33	17.64	18.86	20.00	21.09	23.10	24.95	26.67	28.29	29.82
35	12.52	14.46	16.16	17.70	19.12	20.44	21.68	22.86	25.04	27.04	28.91	30.67	32.32
40	15.50	17.89	20.01	21.91	23.67	25.30	26.84	28.29	30.99	33.48	35.79	37.96	40.01
45	18.62	21.50	24.03	26.33	28.44	30.40	32.24	33.99	37.23	40.22	42.99	45.60	48.07
50	21.83	25.21	28.18	30.87	33.34	35.65	37.81	39.85	43.66	47.16	50.41	53.47	56.36
55	25.09	28.97	32.39	35.48	38.32	40.97	43.45	45.80	50.18	54.20	57.94	61.45	64.78
57	26.40	30.48	34.08	37.33	40.32	43.10	45.72	48.19	52.79	57.02	60.96	64.66	68.15
60	28.35	32.74	36.60	40.10	43.31	46.30	49.11	51.77	56.71	61.25	65.48	69.45	73.21
66.7	32.68	37.74	42.19	46.22	49.92	53.37	56.60	59.66	65.36	70.60	75.47	80.05	84.38
70	34.77	40.15	44.89	49.17	53.11	56.78	60.23	63.48	69.54	75.12	80.30	85.17	89.78
75	37.87	43.73	48.89	53.56	57.85	61.85	65.60	69.15	75.75	81.82	87.46	92.77	97.79
80	40.88	47.20	52.77	57.81	62.44	66.75	70.80	74.63	81.76	88.31	94.41	100.13	105.55
85	43.78	50.55	56.51	61.91	66.87	71.48	75.82	79.92	87.55	94.57	101.09	107.23	113.03
90	46.55	53.76	60.10	65.84	71.11	76.02	80.63	84.99	93.11	100.57	107.51	114.03	120.20
95	49.21	56.82	63.53	69.59	75.17	80.36	85.23	89.84	98.42	106.30	113.64	120.54	127.06
100	51.74	59.74	66.79	73.17	79.03	84.49	89.61	94.46	103.48	111.77	119.48	126.73	133.59

...lated from

$$\left(\frac{65.41 \times s^2}{s^2 + 10{,}000} + \frac{4.56 \times s}{\sqrt{s^2 + 10{,}000}} + 0.065\right)\left(\frac{l}{72.5}\right)^m$$

LS = topographic factor
l = slope length, ft (m × 0.3048)
s = slope steepness,
m = exponent dependent upon slope steepness (0.2 for slopes < 1%, 0.3 for slopes 1 to 3%, 0.4 for slopes 3.5 to 4.5%, and 0.5 for slopes > 5%)

......	1	1.9	2.8

effect of length is not as great as the effect of slope angle: LS increases 30) percent for each doubling of length. For example, on a 2:1 slope, LS doubles ı L is quadrupled:

Slope	2:1	2:1	2:1
Length	30 ft (9.1 m)	60 ft (18.3 m)	120 ft (36.6 m)
LS	9.76	13.81	19.42
Factor increase	1	1.4	2

;, very long slopes and especially, long, steep slopes, should not be con- ted. Those that already exist should not be disturbed.
ope length can be shortened by installing midslope diversions. Local build- odes often require terraces or drainage ditches at specified intervals. Chap-) of the *Uniform Building Code* specifies a 30-ft (9.1-m) interval. (9) Several ›n control manuals recommend 15-ft (4.6-m) intervals between terraces. (2, Because these intervals are defined as vertical rise, the slope length would mewhat longer.
creasing steepness will require use of more land and so must be incorpo- early in the project design. To ensure slope stability, a maximum gradient ıuently recommended by the soils engineer.

Cover Factor C

over factor C is defined as the ratio of soil loss from land under specified ır mulch conditions to the corresponding loss from tilled, bare soil. The C the same as the runoff coefficient C used in the rational method.
the USLE, the C factor reduces the soil loss estimate according to the effec- ss of vegetation and mulch at preventing detachment and transport of soil les. On construction sites, recommended control practices include the seed- grasses and the use of mulches. These measures are often considered "tem- "—they are designed to control erosion primarily during the construction . Permanent landscaping may be added later, or temporary erosion control may be left as a permanent cover. Any product that reduces the amount exposed to raindrop impact will reduce erosion. Table 5.6 lists C factors ious ground covers. The C values for vegetation were obtained from USDA ıtions (14, 20); those for mulch were obtained from Burgess Kay at the sity of California, Davis, who tested materials on experimental plots a rainfall simulator. (11)
en the soil surface is bare, C is 1.0. At the other end of the scale, undis- native vegetation is assigned a value of 0.01; hence the advantage of ng as much existing vegetation as possible is clear. A C value of 0.1 is used

Type of cover	C factor	Soil loss reduction, %
None	1.0	0
Native vegetation (undisturbed)	0.01	99
Temporary seedings:		
90% cover, annual grasses, no mulch	0.1	90
Wood fiber mulch, ¾ ton/acre (1.7 t/ha), with seed†	0.5	50
Excelsior mat, jute†	0.3	70
Straw mulch†		
1.5 tons/acre (3.4 t/ha), tacked down	0.2	80
4 tons/acre (9.0 t/ha), tacked down	0.05	95

*Adapted from Refs. 11, 15, and 20
†For slopes up to 2:1.

if a complete cover of newly seeded annual grasses is well established before the onset of rains.

In many areas, seed and wood fiber mulch are applied hydraulically shortly before the rainy season. The early rains cause the seeds to germinate, but a complete grass cover is not established until at least 4 weeks later. During the germination and early growth period, the wood fiber mulch provides only marginal protection. A C value of 0.5 is an appropriate average representing little protection initially and more thorough protection when the grass is well established.

On bare soils mulch can provide immediate reduction in soil loss, and it performs better than temporary seedings in some cases. Straw mulch is more effective than wood fiber mulch; it reduces loss about 80 percent (C value, 0.2) when it is applied at the rate of 3000 lb/acre (3.4 t/ha) and tacked down. Additional reduction is obtained with 8000 lb/acre (90 t/ha) of straw, but this rate may not be cost-effective.

Wood fiber mulch alone (without seed) provides very little soil loss reduction; it primarily helps seeds to become established so that the new grass can provide the erosion control. Other products, such as jute, excelsior, and paper matting, provide an intermediate level of protection; the C value equals approximately 0.3. Test results of various mulch treatments are presented in Chap. 6.

5.2f Erosion Control Practice Factor P

The erosion control practice factor P is defined as the ratio of soil loss with a given surface condition to soil loss with up-and-down-hill plowing. Practices that reduce the velocity of runoff and the tendency of runoff to flow directly downslope reduce the P factor. In agricultural uses of the USLE, P is used to describe plowing and tillage practices. In construction site applications, P reflects the roughening of the soil surface by tractor treads or by rough grading, raking, or disking.

Appendix B

MONTGOMERY WATSON

Appendix B

Algorithm for Determining Minimum Surface Area for Sedimentation Basin

Assumptions Made in Determining Inflow for Sedimentation Basin Sizing

Sedimentation Basin - Design and Quantities

Sedimentation Basin - Costs

Land Development Costs

Algorithm for Determining Minimum Surface Area for Sedimentation Basin

MONTGOMERY WATSON

BY ML DATE 6-26-95 CLIENT DGC SHEET 1 OF 6

CHKD. BY ____ DESCRIPTION ____ JOB NO. ____

SETTLING BASIN DESIGN

* TO OBTAIN SURFACE AREA OF BASIN, NEED

$$\frac{Q_{in}}{V_s} \frac{ft^3/sec}{ft^2/sec} = A \ ft$$

Q_{in} - design inflow in ft^3/sec * SEE Page 4

V_s = settling velocity of target particle diameter, d
V_s is a function of temperature as well

The settling efficiency is that fraction of particles of a prescribed diameter d trapped in the sed basin @ design Q conditions

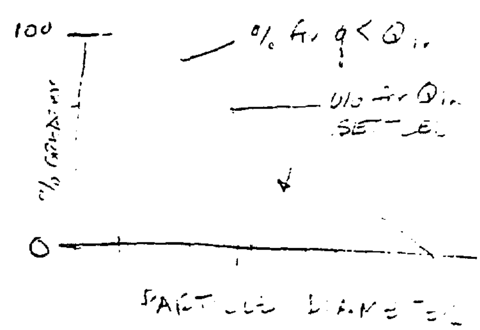
For all $q < Q_{in}$ and given A, V_s + d will be smaller + a greater fraction of particles will be trapped.

This is the trap efficiency of the ...

* TO OBTAIN ANNUAL TRAP EFFICIENCY = % Removal prescribed by II A (1)(c) + (c) management measures need to determine removal rate for each storm for a given year (or average of a number of years).

ASSUMPTIONS:
1. Particle size diameter distrib.

USE 1983 Basin Inlet Composite #1



MONTGOMERY WATSON

BY Mel DATE ______ CLIENT ______ SHEET 2 OF 6
CHKD. BY ______ DESCRIPTION ______ JOB NO. ______

From 1992 Basin Inlet Composite #1:

TABLE 1:

Particle Size (micron)	% greater
0	100
5	90
10	72
20	35
30	12
40	7
50	4
60	

2. Inflow Q for each runoff event

VOL (in ac-ft) + Q_{24} (cfs) for each basin sizing developed based on 24 hr flow

Use 8 hrs as average runoff period length

Then $Q = q_{24} \times \left(\frac{24}{8}\right) = q_8$ for 8-hr basin sizing

3. We have already determined a TSS load (lbs) for each runoff event

4. Particle Settling Velocity

$$V_s = \frac{d^2(\gamma_s - \gamma)}{18\mu} \quad \frac{m}{sec}$$

where d = particle diameter, microns

γ_s = sphere specific weight = 2.6 × 9.8 m/sec²
γ = water specific weight = 1.0 × 9.8 m/sec²

μ = dynamic viscosity of water

= function of temperature [illegible] μ = .0018 Kg/m-sec
= .0015 Kg/m-sec
= .00[illegible] Kg/m-sec

For 0°C, $V_s = (d \times 10^{-6})^2\, 483{,}951\ \frac{m}{sec} = 147{,}508(d \times 10^{-6})^2$ ft/sec

5° F, $V_s = (d \times 10^{-6})^2\, 580{,}7[illegible]\ \frac{m}{sec} = 177{,}010(d \times 10^{-6})^2$ ft/sec

For Juneau, use 5° Feb-Oct; 0° Nov-Jan

Anchorage 5° May-Sep; 0° Oct-April

5. Iterate following steps for each storm (q + lbs) and each land use w/given target % TSS removal.

a. Assume a surface area A

b. For each storm, calculate q_8 from i_{24}

c. Find $V_s = \frac{q_8}{A}$

d. Find d for V_s, based on time of year + temperature

if d < 10 microns, set d = 10 microns

e. Look up d in Table 1 + determine % removed.

Use straight line interpolation.

e.g. for d = 15 microns, % removed = 55.5%

f. Multiply % Removed × lbs TSS for that storm = TSS removed

g. Add up all TSS (lbs) removed for rainfall season

h. Calculate rainfall efficiency $E = \frac{\sum \text{TSS removed}}{\sum \text{TSS in runoff}}$

i. If E <> target TSS % removed

adjust A + iterate steps c through i

MONTGOMERY WATSON

BY ml DATE ________ CLIENT ____________________ SHEET 4 OF 6

CHKD. BY ______ DESCRIPTION ____________________ JOB NO. ________

DETERMINE q for SEC BASIN DESIGN

for Anchorage, we had hourly rainfall data for 1965

In 1965, median storm duration = 8 hrs

VOL from regression equation was for storm event

$$q_{24} = \text{VOL} \times \text{ACRES} \times \frac{43560\ ft^2}{24 \times 3600\ sec} \times \frac{ft}{12\ in} = \quad cfs$$, based on 24 hr duration

But since median storm duration is 8 hrs,

need to compress q_{24} into 8 hrs

$$q_8 = q_{24}\,(24/8)\ cfs$$ ← USE FOR SEC. BASIN DESIGN

No Hourly data available for Juneau, so used same relationship for Juneau as Anchorage.

MONTGOMERY WATSON

BY mul DATE ______ CLIENT ______ SHEET 5 OF 6

CHKD. BY ______ DESCRIPTION ______ JOB NO. ______

CHECK THAT SB VOL LARGE ENOUGH
FOR REQD MIN DET TIME

FOR ANCHORAGE, max $i = 0.2''/hr$ for 2yr 6hr Storm
CHOOSE "WORST CASE" - COMMERCIAL DEVELOPMENT
where - % IMP = 85%
$A = 10$ ac
$q = cia = .85 \cdot .2 \cdot 10 = 1.7$ cfs

FOR 68% REMOVAL (PRE = POST CONDITIONS),

FIND MIN DIAMETER PARTICLE TO SETTLE:

FROM BASIN INLET COMPOSITE #1:

% GREATER	DIAMETER micron
72%	10
35%	20

← 68% ⇒ 11.1 microns

FOR $d = 11.1$ microns V_s (@ 5%) $= \dfrac{(d^2 \cdot 177{,}010}{(10^6)^2}$ ft/sec

$= .000235$ ft/sec

FOR FALL DISTANCE = 1 ft, detention time

$= \text{FALL DIST} \div V_s = \dfrac{1\ \text{ft}}{.000235\ \text{ft/sec}} = 4255$ sec

DETENTION VOLUME = DETENTION TIME × q

$= 4255\ \text{sec} \times 1.7\ \dfrac{ft^3}{sec} = \underline{7234\ ft^3}$

MONTGOMERY WATSON

BY vml DATE ________ CLIENT ________ SHEET 6 OF 6

CHKD. BY ________ DESCRIPTION ________ JOB NO. ________

FIND:

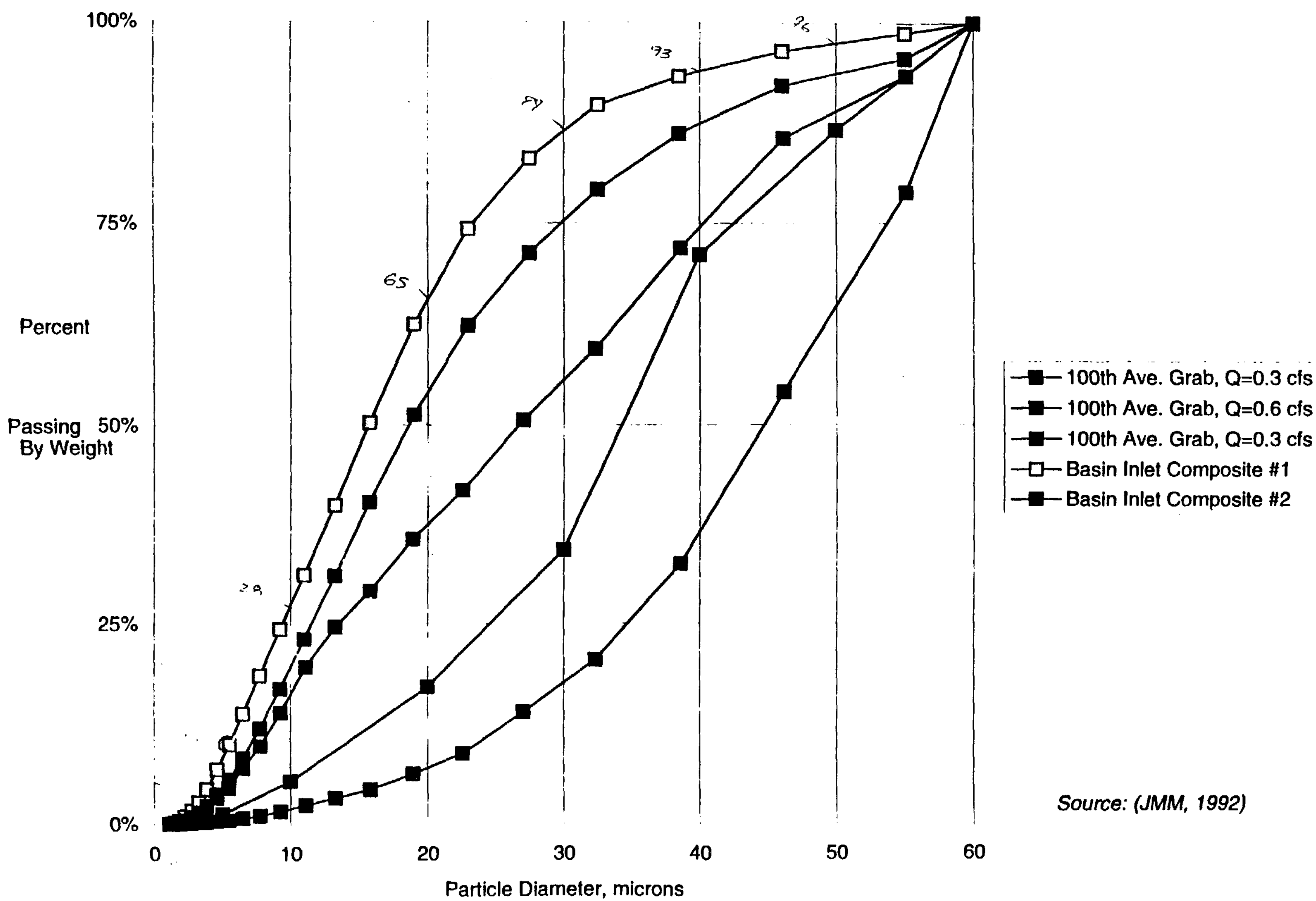
MINIMUM DEPTH FOR SURCHARGE

$7234 = VOL = (20 d_{min} + 4 d_{min}^2)\, 80$

$d_{min} < 2' < 5'$ in design.

THIS WILL HOLD TRUE FOR OTHER BASINS, AS WELL,
SINCE COMMERCIAL BASIN IS "WORST CASE"
(GREATEST RUNOFF).

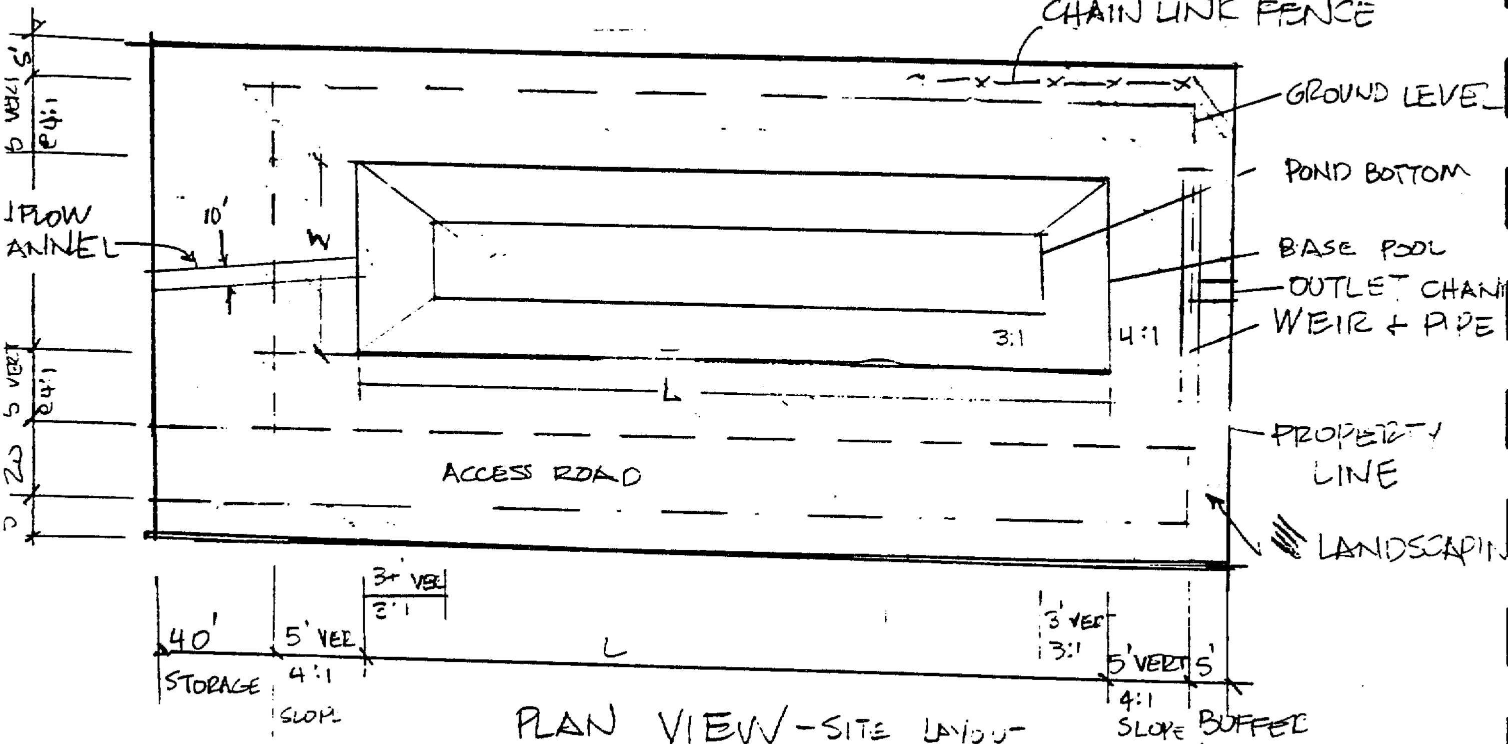
Figure 2-1 Particle Size Distribution Analyses for Suspended Sediment in Storm WaterStorm Water



Sedimentation Basin - Design and Quantities

		units	Anchorage			Juneau	
			Residential	Industrial	Commercial	Residential	Industrial
Sedimentation Basin - Quantities							
Surface area required	A'	sf	90	400	1600	450	2600
Dimensions of base pool	w = max(3*d*2,w=sqrt(A/4))	ft	18	18	20	18	25
	l=4w	ft	72	72	80	72	102
minimum pond surface	Apond	ft	1296	1296	1600	1296	2600
depth (d)	range: 3 to 6 ft	ft	3	3	3	3	3
pond volume	VOLpond=.5*(Ab+A)*d	cf	1944	1944	2586	1944	4844
depth from ground to top of pond (dg)	5	ft	5	5	5	5	5
pond bottom area	Ab=(l-2d(3:1) x (w-2d(3:1))	sf	0	0	124	0	629
ground surface area	Ag=(l+2dg(4:1))*(w+2dg(4:1))	sf	6496	6496	7200	6496	9299
excavation	VOLex=(.5*(A+Ag)+Apond) /27	cy	216	216	259	216	400
Overall site length	Ltot = (40+2*(5,4:1)+l+5)	ft	167	167	175	167	197
Overall site width	Wtot = (5+2*(5,4:1)+w+20+5	ft	88	88	90	88	95
area of site	Atot = Ltot * Wtot	sf	14,696	14,696	15,750	14,696	18,811
inlet/outlet	VOLlet=.5*(3+6)*(40+5(4:1) + 5)*1.5	cy	16	16	16	16	16
Road Surface	Aroad = 20*(Ltot-5)	sf	3,240	3,240	3,400	3,240	3,840
landscaping	SA = (Ltot*Wtot)-Aroad-Apond	sf	10,160	10,160	10,750	10,160	12,371
Concrete on-grade broad crested weir							
width of weir top	T = .67	ft	0.67	0.67	0.67	0.67	0.67
Height of weir-fdn to top	H = 7	ft	7	7	7	7	7
width of weir at fdn	b = T + 2*H(2:1)	ft	28.67	28.67	28.67	28.67	28.67
Length of weir structure	Lweir=w+2*(1*(4:1)+3)	ft	32	32	34	32	39.4950976
End area of weir	Aweir=.5*((b+T)H-(H-.5)+(b+t-1))	sf	10.6	10.6	10.6	10.6	10.6
forms	6*lweir	lf	192	192	204	192	236.970585
wwm	Lweir * (2 * (sqrt(2*H^2)) +	sf	655	655	696	655	808
concrete	Aweir * L weir/27	cy	13	13	13	13	15
Outlet pipe	15	lf	15	15	15	15	15

Prototype Sed basin Design



PLAN VIEW - SITE LAYOUT

A' = surface area required from ~~settling~~ analysis $\frac{Q}{V_s} = A'$

$L:W = 1:4 \Rightarrow W = \sqrt{\frac{A}{4}}$

FROM GEOMETRY, W_{min} = 3' VERT ... = 18'

CHOOSE MAX $\left(18, \sqrt{\frac{A'}{4}}\right)$

CALCULATE $L = 4W$

CALCULATE $A_{POND} = WL$

L = OVERALL SITE LENGTH (40+(5.4)) L + (5.4) + 5 ...

W = OVERALL SITE WIDTH = (5 + (5.4) + W + (5.4) + 20 + 5) ...

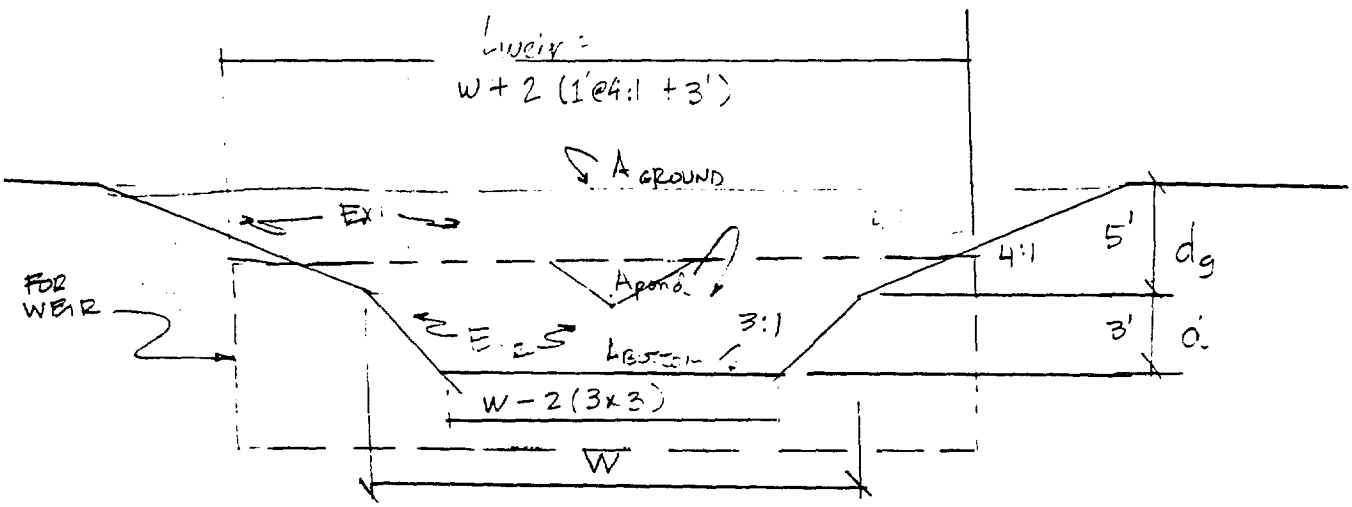
A_{ROAD}: ROAD SURFACE = 20 (L_{TOT} - 5) ...

LANDSCAPE AREA = $L_{TOT} \cdot W_{TOT} - A_{ROAD} - A_{POND}$

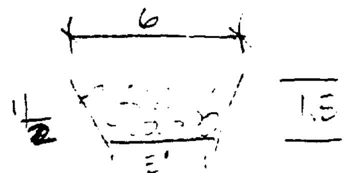
MONTGOMERY WATSON

BY hul DATE 7-3-95 CLIENT ______ SHEET 2 OF 3

CHKD. BY ______ DESCRIPTION STORM WATER CONTROLS JOB NO. ______



CROSS SECTION



INLET + OUTLET -

6' wide rock lined channel · 1½" + stone

Inlet L = 40+5(...) = 60
Outlet L = 5

$A = \frac{(3+6)}{2} \times 1.5 = 6.75\ ft^2$

$Vol = A\,(L_{in} + L_{out}) = \frac{6.75\,(65)}{27} = 16.25\ cy$

Excavation Quantities

Base Pond Area

$A_{BOTTOM} = [W - 2(3\times3)] \times [L - 2(3\times3)]$

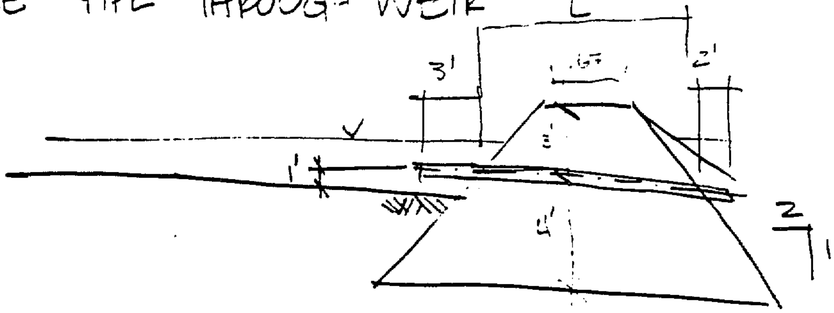
Ground Surface Area

$A_{GROUND} = [W + 2(5\times4)] \times [L + 2(5\times4)]$

MONTGOMERY WATSON

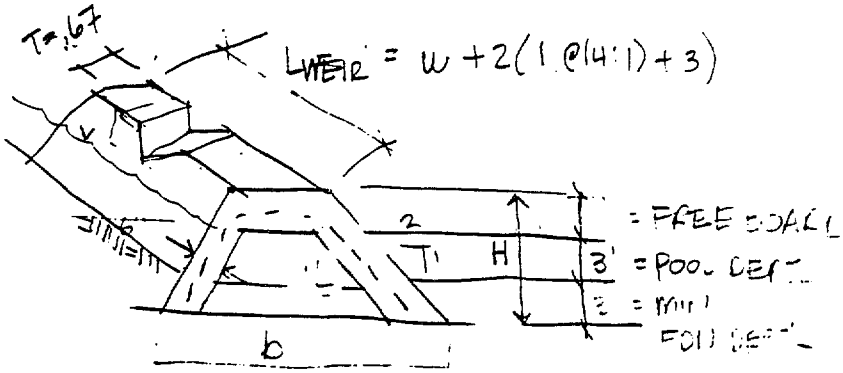
BY mul DATE 7-3-95 CLIENT DGC SHEET 3 OF 3
CHKD. BY ______ DESCRIPTION STORM WATER CONTROLS JOB NO. ______

OUTLET PIPE THROUGH WEIR



Length of pipe $L = 3 + (3 \times 2{:}1) \times 2 + .67 + 2 = 15'$

BROAD CRESTED WEIR



End $A_w = \frac{1}{2}(b+T)H - \frac{1}{2}(H-.5)(b+T-1)$ $b = 2(7 @ 2{:}1) + .67 = 28.67$

$= \frac{1}{2}(28.67+.67)7 - \frac{1}{2}(6.5)(28.67+.67-1) = 10.6\ ft^2$

Length of weir = w + 2(1 @ 4:1 + 3) (from p 2)

SF WWN = $\left[\sqrt{2 \cdot H^2} \cdot 2 + T\right] \times L_{WEIR}$

LF for forms = Lweir × 4

CY concrete = $\frac{A_w L}{27}$

Sedimentation Basin - Costs

		units	Anchorage			Juneau	
			Residential	Industrial	Commercial	Residential	Industrial
Sedimentation Basin - Costs							
from Means 1995 Heavy Construction Cost Data							
Anchorage City Cost Index							
all others	1.37						
forms	1.24						
wwm	1.44						
concrete	1.56						
Juneau - use 105% of Anchorage costs							
Construction Costs							
Land costs	$6 res, $5 ind,$12 com	$/sf	6	5	12	6	5
Land		$	19,440	16,200	40,800	19,440	18,238
	Unit Costs from Means						
Excavation and Grading							
mob/demob	370.00	$/ea	505	505	505	530	530
front end loader	1.48	$/cy	437	437	523	459	848
Outlet							
outlet pipe	25.50	$/lf	522	522	522	548	548
weir							
forms in place	2.11	$/lf	501	501	532	526	649
reinf www	35.00	$/csf	331	331	351	347	429
slab on grade	100.00	$/cy	1,951	1,951	2,073	2,048	2,528
Inlet/Outlet Channel	19.05	$/cy	423	423	423	444	444
Access (road)							
pavement base	5.25	$/sy	2,580	2,580	2,707	2,709	3,210
prepare and roll	1.26	$/sy	619	619	650	650	770
Fencing							
fencing	12.35	$/lf	8,260	8,260	8,597	8,673	10,000
posts	89.00	$/ea	486	486	486	510	510
gate	925.00	$/opng	1,263	1,263	1,263	1,326	1,326
Landscaping							
rough grade	18.55	$/msf	257	257	272	270	329
seed-slope mix	19.20	$/msf	266	266	282	280	340
Subtotal		$	27,308	24,068	49,086	27,701	28,195
25% Contingency		$	6,827	6,017	12,271	6,925	7,049
15% Engineering		$	4,096	3,610	7,363	4,155	4,229
TCC - Total Capital Cost		$	38,231	33,695	68,720	38,782	39,472
cost per unit volume of pond		$	20	17	27	20	8
Annualized - 10%, 25 yrs		$	4,212	3,712	7,571	4,273	4,349
0.10	rate						
25	yrs						
Site Maintenance							
Frequent Site Maintenance							
mowing-10x/yr	1.68	$/msf	233	233	247	245	298
watering - water 1" - 5x/yr	11.80	$/msf	818	818	866	859	1,046
watering -hose set-up - 5x/y	2.78	$/msf	193	193	204	202	246
fertilizer2x/yr	2.76	$/msf	77	77	81	80	98
weed control 2x/yr	0.28	$/msf	8	8	8	8	10
Subtotal		$	1,328	1,328	1,405	1,395	1,698
Occasional basin cleanout/every 8 yrs							
mob-demob	370	$/ea	505	505	505	530	505
.5 pond volume			36	36	48	36	90
excavate @ .5 pond vol	1.48	$/cy	73	73	97	76	190
dispose - haul 8 hrs	2.88	$/cy	142	142	188	149	370
reseed- .25 of landscaped site	19.20	$/msf	7	7	8	8	9
Subtotal		$	763	763	846	799	1,165
present value for 8th yr		$	4,736	4,736	5,252	4,962	7,233
present value for 16th yr		$	7,708	7,708	8,547	8,075	11,771
present value for 24th yr		$	9,572	9,572	10,615	10,028	14,619
annualize sum of 3 cleanou		$	2,425	2,425	2,690	2,541	3,704
Total O&M		$	3,754	3,754	4,095	3,936	5,402
TAC - Total Annual Cost		$	7,966	7,466	11,666	8,208	9,751
TAC per developed acre		$	1,593	747	1,167	1,642	488

Land Development Costs

		units	Anchorage			Juneau	
			Residential	Industrial	Commercial	Residential	Industrial
Land Use Development Costs							
Commercial and Industrial							
	Development Area	acres	5	10	10	5	20
	Development % Impervious	%	38	50	85	40	50
buildingand site dev costs from Means		$/sf		50	64		50
Anchorage Cost Index:	126.7	%					
	land cost	$	1,306,800	2,178,000	5,227,200	1,306,800	4,138,200
	bldg size	sf		108,900	123,420		217,800
	bldg and site dev cost	$		6,912,613	9,992,244		14,516,487
Total Site Development Cost		$		9,090,613	15,219,444		18,654,687
Annualization		$		1,001,495	1,676,697		2,055,151
0.1	rate						
25	period						
TCC as a Share of Project Cost		%		0.371	0.452		0.212
TAC as Share of Annualized Project Cost		%		0.745	0.696		0.474
Residential							
number of houses			18			18	
median house price		$	109,700			113,500	
median annual mortgage		$	9,111			9,427	
15% down, 30 yrs, .08 rate + 10%insurance, taxes							
median household income		$	43,946			47,924	
TCC per house/average house price		%	1.936			1.898	
TCC/land price		%	2.926			2.968	
TAC per house/average house price		%	4.857			4.838	
TAC per house/median household income		%	1.007			0.952	